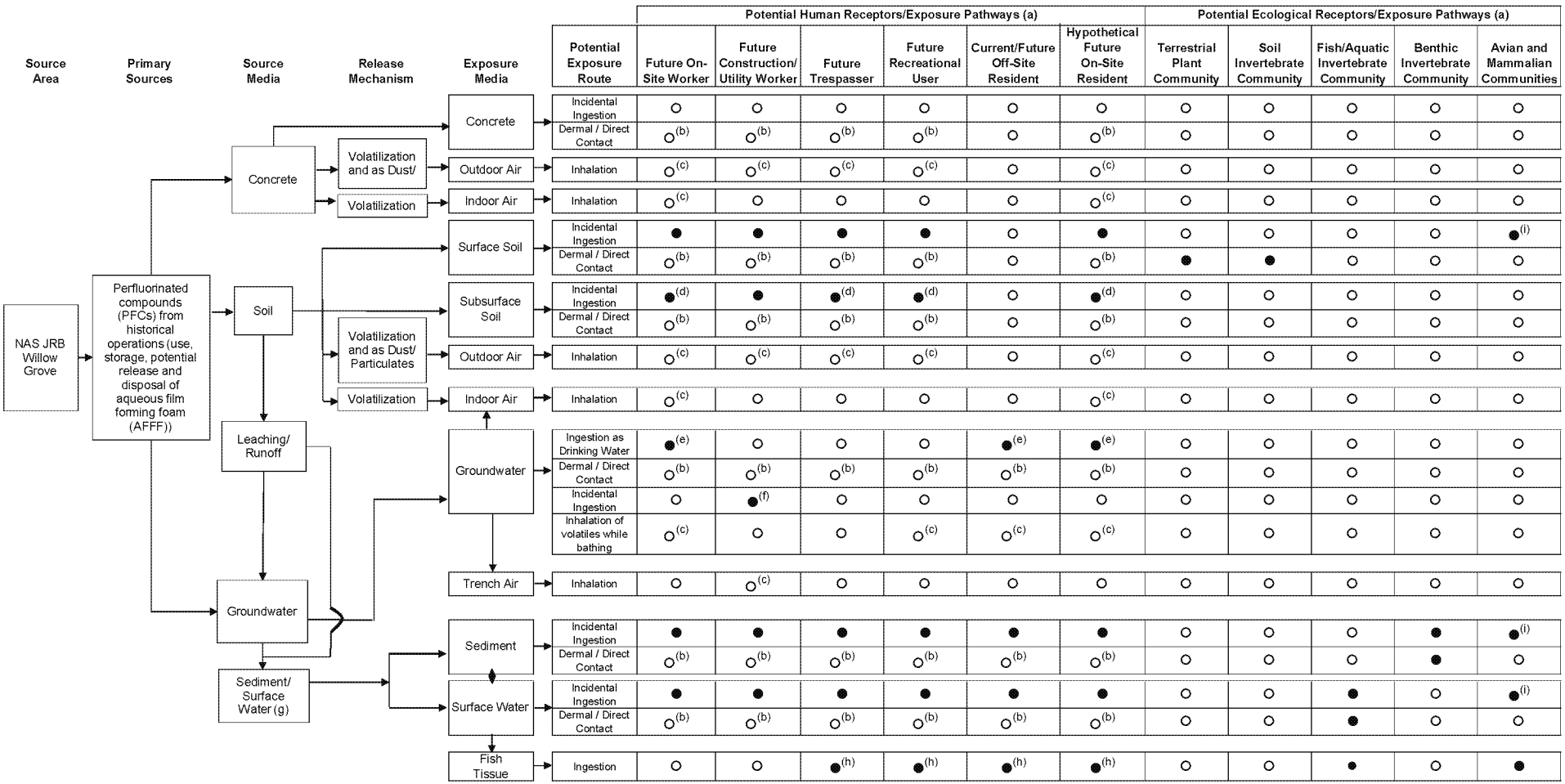
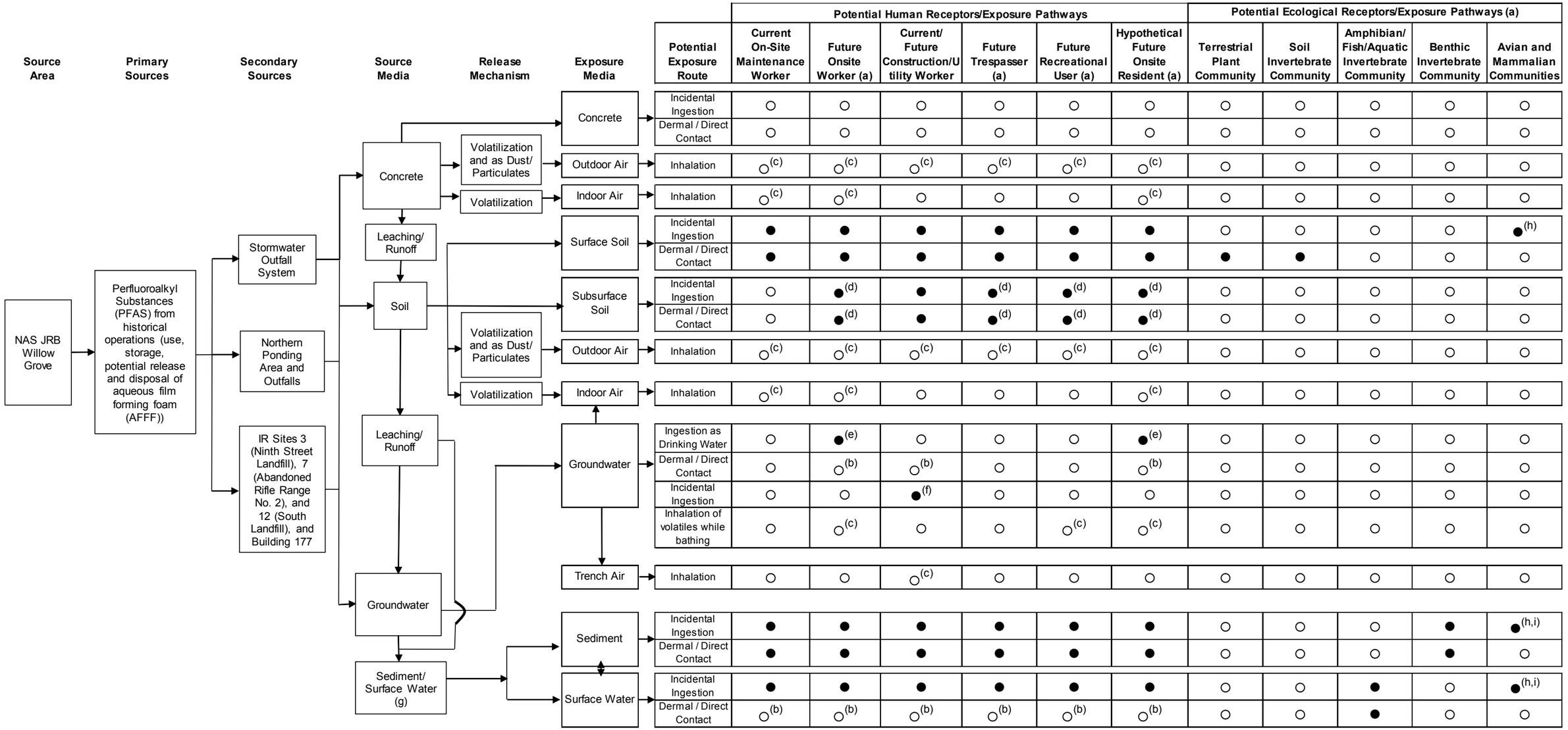
Figure
Conceptual Site Model
NAS JRB Willow Grove, PA



Source Area	Primary Sources	Source Media	Release Mechanism	Exposure Media	Potential Exposure Route	Future On-Site Worker	Future Construction/ Utility Worker	Future Trespasser	Future Recreational User	Current/Future Off-Site Resident	Hypothetical Future On-Site Resident	Terrestrial Plant Community	Soil Invertebrate Community	Fish/Aquatic Invertebrate Community	Benthic Invertebrate Community	Avian and Mammalian Communities
						Potential Human Receptors/Exposure Pathways (a)						Potential Ecological Receptors/Exposure Pathways (a)				
NAS JRB Willow Grove	Perfluorinated compounds (PFCs) from historical operations (use, storage, potential release and disposal of aqueous film forming foam (AFFF))	Concrete		Concrete	Incidental Ingestion	○	○	○	○	○	○	○	○	○	○	○
					Dermal / Direct Contact	○ (b)	○ (b)	○ (b)	○ (b)	○	○ (b)	○	○	○	○	○
			Volatilization and as Dust/	Outdoor Air	Inhalation	○ (c)	○ (c)	○ (c)	○ (c)	○	○ (c)	○	○	○	○	○
			Volatilization	Indoor Air	Inhalation	○ (c)	○	○	○	○	○ (c)	○	○	○	○	○
		Soil		Surface Soil	Incidental Ingestion	●	●	●	●	○	●	○	○	○	○	● (i)
					Dermal / Direct Contact	○ (b)	○ (b)	○ (b)	○ (b)	○	○ (b)	●	●	○	○	○
				Subsurface Soil	Incidental Ingestion	● (d)	●	● (d)	● (d)	○	● (d)	○	○	○	○	○
					Dermal / Direct Contact	○ (b)	○ (b)	○ (b)	○ (b)	○	○ (b)	○	○	○	○	○
			Volatilization and as Dust/ Particulates	Outdoor Air	Inhalation	○ (c)	○ (c)	○ (c)	○ (c)	○	○ (c)	○	○	○	○	○
			Volatilization	Indoor Air	Inhalation	○ (c)	○	○	○	○	○ (c)	○	○	○	○	○
		Leaching/ Runoff		Groundwater	Ingestion as Drinking Water	● (e)	○	○	○	● (e)	● (e)	○	○	○	○	○
					Dermal / Direct Contact	○ (b)	○ (b)	○ (b)	○ (b)	○ (b)	○ (b)	○	○	○	○	○
					Incidental Ingestion	○	● (f)	○	○	○	○	○	○	○	○	○
					Inhalation of volatiles while bathing	○ (c)	○	○	○ (c)	○ (c)	○ (c)	○	○	○	○	○
				Trench Air	Inhalation	○	○ (c)	○	○	○	○	○	○	○	○	○
		Groundwater		Sediment	Incidental Ingestion	●	●	●	●	●	●	○	○	○	●	● (i)
					Dermal / Direct Contact	○ (b)	○ (b)	○ (b)	○ (b)	○ (b)	○ (b)	○	○	○	●	○
		Sediment/ Surface Water (g)		Surface Water	Incidental Ingestion	●	●	●	●	●	●	○	○	●	○	● (i)
					Dermal / Direct Contact	○ (b)	○ (b)	○ (b)	○ (b)	○ (b)	○ (b)	○	○	●	○	○
				Fish Tissue	Ingestion	○	○	● (h)	● (h)	● (h)	● (h)	○	○	●	○	●

Notes:
● Potentially complete pathway.
○ Pathway considered to be incomplete or insignificant.

(a) Based on potential future site use. Current on-site workers access the site periodically/intermittently, therefore current exposure is considered to be insignificant. The Site is fenced in and access is restricted, therefore a current trespasser scenario is not considered a potentially complete pathway.
(b) Dermal contact is not considered a complete pathway due to the lack of chemical-specific information relative to PFCs to calculate their absorption through the skin. The dermal exposure pathway cannot be estimated using U.S. EPA's Risk Assessment Guidance for Superfund (RAGS) Part E Dermal Risk Assessment Guidance methodology (U.S. EPA, 2004) as these chemicals are said to be outside of the model's effective predictive domain (EPD) and use of the model is not recommended due to high uncertainty.
(c) Inhalation toxicity values are not currently available for PFCs, therefore the inhalation pathway cannot be quantified.
(d) Exposure to subsurface soil is considered a potentially complete pathway for the future use scenario only, assuming deeper soils may be brought to the surface and made available for contact during development for future use.
(e) Drinking water is currently provided by municipal water. Groundwater at the Site is not currently used for potable use. However, with the exception of IR Site 5, there are no restrictions on groundwater, therefore groundwater ingestion as drinking water is a potentially complete pathway (excluding IR Site 5) under a hypothetical future use scenario if groundwater becomes a source of potable water.
(f) The associated pathway is potentially complete if the water table is equal or less than 15 feet below ground surface, making it available for contact by a construction worker.
(g) Sediment and surface water pathways are assumed to be potentially complete for the Recreational Pond, North Ponding Area, Pennypack Creek, Park Creek, and Park Creek Tributary.
(h) Fish tissue ingestion assumed to be potentially complete for Pennypack and Park Creeks.
(i) Bioaccumulation pathway also expected to be potentially complete for Pennypack Creek and Park Creek and for terrestrial areas which provide habitat for wildlife. Areas developed for industrial, commercial, or residential use are unlikely to provide significant habitat for avian and mammalian communities so exposure pathways would not be complete under those scenarios.



Source Area	Primary Sources	Secondary Sources	Source Media	Release Mechanism	Exposure Media	Potential Exposure Route	Current On-Site Maintenance Worker	Future Onsite Worker (a)	Current/ Future Construction/Utility Worker	Future Trespasser (a)	Future Recreational User (a)	Hypothetical Future Onsite Resident (a)	Terrestrial Plant Community	Soil Invertebrate Community	Amphibian/ Fish/Aquatic Invertebrate Community	Benthic Invertebrate Community	Avian and Mammalian Communities
							Potential Human Receptors/Exposure Pathways						Potential Ecological Receptors/Exposure Pathways (a)				
NAS JRB Willow Grove	Perfluoroalkyl Substances (PFAS) from historical operations (use, storage, potential release and disposal of aqueous film forming foam (AFFF))	Stormwater Outfall System; Northern Ponding Area and Outfalls; IR Sites 3 (Ninth Street Landfill), 7 (Abandoned Rifle Range No. 2), and 12 (South Landfill), and Building 177	Concrete		Concrete	Incidental Ingestion	○	○	○	○	○	○	○	○	○	○	○
						Dermal / Direct Contact	○	○	○	○	○	○	○	○	○	○	○
			Concrete	Volatilization and as Dust/ Particulates	Outdoor Air	Inhalation	○(c)	○(c)	○(c)	○(c)	○(c)	○(c)	○	○	○	○	○
				Volatilization	Indoor Air	Inhalation	○(c)	○(c)	○	○	○	○(c)	○	○	○	○	○
			Leaching/ Runoff		Surface Soil	Incidental Ingestion	●	●	●	●	●	●	○	○	○	○	●(h)
						Dermal / Direct Contact	●	●	●	●	●	●	●	●	○	○	○
			Soil		Subsurface Soil	Incidental Ingestion	○	●(d)	●	●(d)	●(d)	●(d)	○	○	○	○	○
						Dermal / Direct Contact	○	●(d)	●	●(d)	●(d)	●(d)	○	○	○	○	○
				Volatilization and as Dust/ Particulates	Outdoor Air	Inhalation	○(c)	○(c)	○(c)	○(c)	○(c)	○(c)	○	○	○	○	○
				Volatilization	Indoor Air	Inhalation	○(c)	○(c)	○	○	○	○(c)	○	○	○	○	○
			Leaching/ Runoff		Groundwater	Ingestion as Drinking Water	○	●(e)	○	○	○	●(e)	○	○	○	○	○
						Dermal / Direct Contact	○	○(b)	○(b)	○	○	○(b)	○	○	○	○	○
						Incidental Ingestion	○	○	●(f)	○	○	○	○	○	○	○	○
						Inhalation of volatiles while bathing	○	○(c)	○	○	○(c)	○(c)	○	○	○	○	○
					Trench Air	Inhalation	○	○	○(c)	○	○	○	○	○	○	○	○
			Groundwater		Sediment	Incidental Ingestion	●	●	●	●	●	●	○	○	○	●	●(h,i)
						Dermal / Direct Contact	●	●	●	●	●	●	○	○	○	●	○
			Sediment/ Surface Water (g)		Surface Water	Incidental Ingestion	●	●	●	●	●	●	○	○	●	○	●(h,i)
						Dermal / Direct Contact	○(b)	○(b)	○(b)	○(b)	○(b)	○(b)	○	○	●	○	○

Notes:
- ● Potentially complete pathway.
- ○ Pathway considered to be incomplete or insignificant.
- (a) Based on potential future Site use. The Site is fenced in, access is restricted, and the Site is patrolled by police. Therefore, a current trespasser scenario is not considered a potentially complete pathway.
- (b) Dermal contact with PFOS, PFOA, and PFBS in water is not considered a complete pathway due to the lack of chemical-specific information to calculate their absorption through the skin. The dermal exposure pathway cannot be estimated using US EPA's Risk Assessment Guidance for Superfund (RAGS) Part E Dermal Risk Assessment Guidance methodology (US EPA, 2004) as these chemicals are said to be outside of the model's effective predictive domain (EPD) and use of the model is not recommended due to high uncertainty.
- (c) Inhalation toxicity values are not currently available for PFAS, therefore the inhalation pathway cannot be quantified.
- (d) Exposure to subsurface soil is considered a potentially complete pathway for the future use scenario only, assuming deeper soils may be brought to the surface and made available for contact during development for future use.
- (e) Drinking water is currently provided to the area by municipal water. Onsite groundwater is not currently used for potable use. However, with the exception of IR Site 5, there are no restrictions on groundwater, therefore groundwater ingestion as drinking water is a potentially complete pathway (excluding IR Site 5) under a hypothetical future use scenario if onsite groundwater becomes a source of potable water.
- (f) The associated pathway is potentially complete if the water table is equal or less than 15 feet below ground surface, making it available for contact by a construction/utility worker.
- (g) Sediment and surface water pathways are assumed to be potentially complete for on and/or offsite water bodies as applicable.
- (h) Bioaccumulation pathway also expected to be potentially complete for onsite and/or offsite water bodies and for terrestrial areas which provide habitat for wildlife. Areas developed for industrial, commercial, or residential use are unlikely to provide significant habitat for avian and mammalian communities so exposure pathways would not be complete under those scenarios.
- (i) Bioaccumulation pathway for aquatic reptiles (e.g., turtles) may also be complete for onsite and/or offsite water bodies .

RESOLUTION CONSULTANTS

Drawn:	MKL	9/26/2018
Approved:	PJ	9/26/2018
Project #:	60276503	

FIGURE 6-1
CONCEPTUAL SITE MODEL

NAS JRB
WILLOW GROVE, PENNSYLVANIA

Path: S:\Projects\IMS\USNAVY\Maps\NASJRB Willow Grove\2018 RI\Figure 6-1 Conceptual Site Model.mxd

From:	Lin, Willie CIV NAVFAC HQ, BRAC PMO
To:	Preston, Gregory C CIV NAVFAC HQ, BRAC PMO; Helland, Brian J CIV NAVFAC MIDLANT, EV; Dale, Jeffrey M CIV NAVFAC MIDLANT, EV; Barclift, David J CIV NAVFAC LANT, EV; Schy, Martin NAVFAC HQ, BRAC PMO; Rugh, James L CIV NAVFAC HQ, BRAC PMO
CC:	Fielding, Thuane B CIV NAVFAC HQ, BRAC PMO; Lansdale, Lawrence L CIV NAVFAC HQ, BRAC PMO
Sent:	3/11/2016 3:58:37 PM
Subject:	RE: PFCs and fish consumption

Aye aye!

-----Original Message-----
From: Preston, Gregory C CIV NAVFAC HQ, BRAC PMO
Sent: Friday, March 11, 2016 10:27 AM
To: Lin, Willie CIV NAVFAC HQ, BRAC PMO; Helland, Brian J CIV NAVFAC MIDLANT, EV; Dale, Jeffrey M CIV NAVFAC MIDLANT, EV; Barclift, David J CIV NAVFAC LANT, EV; Schy, Martin NAVFAC HQ, BRAC PMO; Rugh, James L CIV NAVFAC HQ, BRAC PMO
Cc: Fielding, Thuane B CIV NAVFAC HQ, BRAC PMO; Lansdale, Lawrence L CIV NAVFAC HQ, BRAC PMO
Subject: RE: PFCs and fish consumption

Willie,

Please hold off on that course of action. We are still struggling to get our hands around the latest request for human health study.

Fish impact and bio-accumulation is a new issue that we will need to discuss with Lawrence, and probably DASN(E) as it could result in a precedent setting protocol. Please review with Lawrence (who I added to the string). Also Brian and Dave Barclift should participate to discuss risk assessment and probabilities. Thanks!

v/r,
Greg.

-----Original Message-----
From: Lin, Willie CIV NAVFAC HQ, BRAC PMO
Sent: Friday, March 11, 2016 9:54 AM
To: Helland, Brian J CIV NAVFAC MIDLANT, EV; Dale, Jeffrey M CIV NAVFAC MIDLANT, EV; Barclift, David J CIV NAVFAC LANT, EV; Schy, Martin NAVFAC HQ, BRAC PMO; Rugh, James L CIV NAVFAC HQ, BRAC PMO
Cc: Preston, Gregory C CIV NAVFAC HQ, BRAC PMO; Fielding, Thuane B CIV NAVFAC HQ, BRAC PMO
Subject: PFCs and fish consumption

Team:

I'm pondering the challenge of PFCs in fish (for human consumption) in the waterbody near NASJRB Willow Grove, Horsham Air Station, and NAWC Warminster due to PFCs.

As we know, recommendation number 3 of the ATSDR Letter Health Consultation for Former NAWC Warminster states, "the Navy should conduct follow-up characterization of other non-drinking water potential environmental exposure pathways to PFCs in the site area (e.g., fish), if site information indicates these other exposures pathways might exist."

I know there is very little waterway data for PFCs, and no actual fish tissue sampling, but PADEP has our 2014 stream sampling near HAGS, and the Air Guard is supposed to be sampling their storm outfalls for PFCs as part of their investigation.

Here is the PA 2016 fish consumption public health advisory
http://fishandboat.com/fishpub/summary/sumconsumption.pdf

I think it's likely that a similar ATSDR comment about fish consumption will be provided for the upcoming Letter Health Consultation for Willow Grove, but the recent media and elected official interest in PFCs reflects a desire for prompt action. By the way, ATSDR just completed a draft health consultation for fish at former Wurtsmith AFB, Michigan on March 1st.
http://www.atsdr.cdc.gov/HAC/pha/WAFBFish/WAFB_Fish_HC(PC)Final_03-1-2016_508.pdf

I'm considering an e-mail request to PADEP (Colin Wade), with copy to the FFA team, suggesting that DEP consider a health advisory for PFCs in fish used for consumption.

Thoughts?

Thanks and VR/
Willie

-----Original Message-----
From: Dale, Jeffrey M CIV NAVFAC MIDLANT, EV
Sent: Thursday, January 28, 2016 10:31 AM
To: Barclift, David J CIV NAVFAC LANT, EV
Cc: Helland, Brian J CIV NAVFAC MIDLANT, EV; Lin, Willie CIV NAVFAC HQ, BRAC PMO
Subject: PFCs and fish consumption question

Dave

At yesterday's TRC meeting for NAWC Warminster, Lora Werner of ATSDR questioned whether we were considering the consumption of fish pathway in the RI for NAWC Warminster. My response was reiterating that we were sampling surface water and sediment. Willie is concerned that we need a more complete response while conducting the RIs for both Warminster and Willow Grove. Do you know if there is enough data available to identify the concentration of PFCs in surface water that would contribute to unacceptable concentrations of PFCs in fish tissue? I know there are different PFCs and different fish species so this is not an easy question. I can ensure the RI for Warminster evaluates the fish consumption pathway if prudent to do so.

Thanks for any info.

Jeff

This link is for some older data from DRBC on PFCs in fish in the Delaware river.
http://www.nj.gov/drbc/library/documents/emerging-contaminants_nov2009.pdf

Existing PA fish consumption advisories are here, and include all of Little Neshaminy Creek basin for Carp due to PCBs. Willie thinks leveraging PADEP involvement (of which PA fish and boat commission is a component) would be worthwhile.

http://fishandboat.com/fishpub/summary/sumconsumption.pdf

From: Schirmer, Robert G CIV NAVFAC MIDLANT, EV

To: Nashold, Elizabeth A CIV NAVFAC MIDLANT, EV BLC; Nehm, Lindsay R CIV OPNAV, N45; Barclift, David J CIV NAVFAC LANT, EV; Berkoski, Daniel T CIV NAVSEA, SEA 05; Blodgett, Wayne CIV NAVFAC HQ, EV; Brant, Byron C CIV NAVFAC LANT, EV; Brown, Kim P CIV NAVFAC HQ, EV; Corack, Jennifer M CIV NAVFAC Atlantic, EV; Duchnak, Laura S CIV NAVFAC HQ, BRAC PMO; Dumenigo, Mario O CIV NAVFAC HQ, EV; Greek, Patricia Z CIV CNIC, N452; Hayes, Dan E CIV NAVFAC HQ, EV; Hellman, David H CIV NAVFAC HQ, BRAC PMO; Holmes, Wanda L CIV OPNAV, N45; Hunstad, Mary P CIV NAVSEA HQ, SEA 05; Laitila, Jeffrey P CIV NAVFAC MIDLANT, EV; Lansdale, Lawrence L CIV NAVFAC HQ, BRAC PMO; Porter, Christine H CIV CNIC HQ, N45; Preston, Gregory C CIV NAVFAC HQ, BRAC PMO; Sadorra, Robert A CIV NAVFAC HQ, EV; Person, Roberta CIV NAVFAC HQ, EV; Hayes, Dan E CIV NAVFAC HQ, EV; Murray, Christopher R CIV NAVFAC HQ, EV; Pletke, Mike CIV OPNAV, N45; Holmes, Wanda L CIV OPNAV, N45; Glover, Carl CIV CNIC HQ, N3; Gaumont, Dan CIV CNIC HQ, N30; Simone, Joseph A CIV NAVFAC HQ, CI; Curry, Charles J CIV NAVSUP, N41; john.farley@nrl.navy.mil

CC: Mach, Richard CIV OASN (EI&E), ODASN (Environment); Coghlan, Gunarti H CIV NAVFAC HQ, ENV; Frederickson, Joshua M CIV OPNAV, N45; Rudroff, Jim CIV OASN (EI&E), ODASN Environment; Chamberlayne, John H CIV NAVFAC MIDLANT, EV; Cotnoir, David CIV NAVFAC MIDLANT, EV; Winslow, Phillip S Jr CIV NAVFAC MIDLANT, EV; Gonzalez, Victor R CIV NAVFAC MIDLANT, EV; Laughmiller, Lance S CIV NAVFAC MIDLANT, EV; Jones, Angela CIV NAVFAC MIDLANT, EV; Kowalski, Thomas CIV NAVFAC MIDLANT, EV; Johnson, Nina M CIV NAVFAC MIDLANT, IPTNORTH; Murray, Brian S CIV NAVFAC MIDLANT, IPTNORTH; Will, Katherine CIV NAVFAC MIDLANT, Counsel; Maule, Michael R CIV NAVFAC MIDLANT, Counsel; Yacono, Dominick G CIV CNRMA, N00L; Mcbride, Sean A CIV CNRMA, N00L; Cirvello, Joe R CIV NAVFAC LANT, EV BLM; Hayes, Dan E CIV NAVFAC HQ, EV; Person, Roberta CIV NAVFAC HQ, EV; Blodgett, Wayne CIV NAVFAC HQ, EV; Brown, Kim P CIV NAVFAC HQ, EV; Sadorra, Robert A CIV NAVFAC HQ, EV

Sent: 4/15/2016 7:40:48 PM

Subject: RE: DON PFC Strategy - Comments due 15 April

Attachments: Additional Technical PFC Comments 4-15-16.docx

Pls find attached the word document noted below for your consideration

-----Original Message-----
From: Nashold, Elizabeth A CIV NAVFAC MIDLANT, EV BLC
Sent: Friday, April 15, 2016 3:30 PM
To: Nehm, Lindsay R CIV OPNAV, N45; Barclift, David J CIV NAVFAC LANT, EV; Berkoski, Daniel T CIV NAVSEA, SEA 05; Blodgett, Wayne CIV NAVFAC HQ, EV; Brant, Byron C CIV NAVFAC LANT, EV; Brown, Kim P CIV NAVFAC HQ, EV; Corack, Jennifer M CIV NAVFAC Atlantic, EV; Duchnak, Laura S CIV NAVFAC HQ, BRAC PMO; Dumenigo, Mario O CIV NAVFAC HQ, EV; Greek, Patricia Z CIV CNIC, N452; Hayes, Dan E CIV NAVFAC HQ, EV; Hellman, David H CIV NAVFAC HQ, BRAC PMO; Holmes, Wanda L CIV OPNAV, N45; Hunstad, Mary P CIV NAVSEA HQ, SEA 05; Laitila, Jeffrey P CIV NAVFAC MIDLANT, EV; Lansdale, Lawrence L CIV NAVFAC HQ, BRAC PMO; Porter, Christine H CIV CNIC HQ, N45; Preston, Gregory C CIV NAVFAC HQ, BRAC PMO; Sadorra, Robert A CIV NAVFAC HQ, EV; Schirmer, Robert G CIV NAVFAC MIDLANT, EV; Person, Roberta CIV NAVFAC HQ, EV; Hayes, Dan E CIV NAVFAC HQ, EV; Murray, Christopher R CIV NAVFAC HQ, EV; Pletke, Mike CIV OPNAV, N45; Holmes, Wanda L CIV OPNAV, N45; Glover, Carl CIV CNIC HQ, N3; Gaumont, Dan CIV CNIC HQ, N30; Simone, Joseph A CIV NAVFAC HQ, CI; Curry, Charles J CIV NAVSUP, N41; john.farley@nrl.navy.mil
Cc: Mach, Richard CIV OASN (EI&E), ODASN (Environment); Coghlan, Gunarti H CIV NAVFAC HQ, ENV; Frederickson, Joshua M CIV OPNAV, N45; Rudroff, Jim CIV OASN (EI&E), ODASN Environment; Schirmer, Robert G CIV NAVFAC MIDLANT, EV; Chamberlayne, John H CIV NAVFAC MIDLANT, EV; Cotnoir, David CIV NAVFAC MIDLANT, EV; Winslow, Phillip S Jr CIV NAVFAC MIDLANT, EV; Gonzalez, Victor R CIV NAVFAC MIDLANT, EV; Laughmiller, Lance S CIV NAVFAC MIDLANT, EV; Jones, Angela CIV NAVFAC MIDLANT, EV; Kowalski, Thomas CIV NAVFAC MIDLANT, EV; Johnson, Nina M CIV NAVFAC MIDLANT, IPTNORTH; Murray, Brian S CIV NAVFAC MIDLANT, IPTNORTH; Will, Katherine CIV NAVFAC MIDLANT, Counsel; Maule, Michael R CIV NAVFAC MIDLANT, Counsel; Yacono, Dominick G CIV CNRMA, N00L; Mcbride, Sean A CIV CNRMA, N00L; Cirvello, Joe R CIV NAVFAC LANT, EV BLM; Hayes, Dan E CIV NAVFAC HQ, EV; Person, Roberta CIV NAVFAC HQ, EV; Blodgett, Wayne CIV NAVFAC HQ, EV; Brown, Kim P CIV NAVFAC HQ, EV; Sadorra, Robert A CIV NAVFAC HQ, EV
Subject: RE: DON PFC Strategy - Comments due 15 April

Lindsay,
Here are combined NAVFAC ML/NRMA comments embedded into the draft strategy.

I've also included a separate word document with additional technical comments/recommendations for consideration.

Some general thoughts for consideration:

(1) On base alternate drinking water: Definitive written guidance related to PFCs, provision of bottled water, and fund source in the event of PFC exceedances would be helpful to assist in the acquisition process for this water. (This process was especially difficult for Fentress because of the existing guidance and requirements for provision of bottled water.)

(2) Evolving PFC universe: Since the world of environmental concerns with PFCs is just developing, consider developing the strategy to be flexible enough to account for more PFCs than just PFOA/PFOS; as well as the other routes of exposure (more than ingestion) that may be promulgated in the future.

(3) Timeline for response in the event of exceedances: Recommend tab or addendum that discusses expectation/actions for response in the event of exceedances, including actions when both unvalidated and validated data is received and chain of command coordination or notifications. (MIDLANT can assist in this development based on recent experiences :-)

(4) Actions below PHA but above 25% of PHA: As thresholds are lowered, consider whether we will continue to adopt current protocol for notification and monitoring for these results. (I will send separate rationale for this issue.)

Thank you for providing us the opportunity for comment!

Sincerely and V/r,
Liz

Liz Nashold
CNRMA Environmental Director and
NAVFAC MIDLANT Environmental Business Line Coordinator
1510 Gilbert St Room 3300 Norfolk VA 23511-2737
(w) 757-341-0360
(c) 757-449-6645

-----Original Message-----
From: Nehm, Lindsay R CIV OPNAV, N45
Sent: Tuesday, April 05, 2016 3:11 PM
To: Barclift, David J CIV NAVFAC LANT, EV; Berkoski, Daniel T CIV NAVSEA, SEA 05; Blodgett, Wayne CIV NAVFAC HQ, EV; Brant, Byron C CIV NAVFAC LANT, EV; Brown, Kim P CIV NAVFAC HQ, EV; Corack, Jennifer M CIV NAVFAC Atlantic, EV; Duchnak, Laura S CIV NAVFAC HQ, BRAC PMO; Dumenigo, Mario O CIV NAVFAC HQ, EV; Greek, Patricia Z CIV CNIC, N452; Hayes, Dan E CIV NAVFAC HQ, EV; Hellman, David H CIV NAVFAC HQ, BRAC PMO; Holmes, Wanda L CIV OPNAV, N45; Hunstad, Mary P CIV NAVSEA HQ, SEA 05; Laitila, Jeffrey P CIV NAVFAC MIDLANT, EV; Lansdale, Lawrence L CIV NAVFAC HQ, BRAC PMO; Nashold, Elizabeth A CIV NAVFAC MIDLANT, EV BLC; Porter, Christine H CIV CNIC HQ, N45; Preston, Gregory C CIV NAVFAC HQ, BRAC PMO; Sadorra, Robert A CIV NAVFAC HQ, EV; Schirmer, Robert G CIV NAVFAC MIDLANT, EV; Person, Roberta CIV NAVFAC Washington, EV; Hayes, Dan E CIV NAVFAC HQ, EV; Murray, Christopher R CIV NAVFAC HQ, EV; Pletke, Mike CIV OPNAV, N45; Holmes, Wanda L CIV OPNAV, N45; Glover, Carl CIV CNIC HQ, N3; Gaumont, Dan CIV CNIC HQ, N30; Simone, Joseph A CIV NAVFAC HQ, CI; Curry, Charles J CIV NAVSUP, N41; john.farley@nrl.navy.mil
Cc: Mach, Richard CIV OASN (EI&E), ODASN (Environment); Coghlan, Gunarti H CIV NAVFAC HQ, ENV; Frederickson, Joshua M CIV OPNAV, N45; Rudroff, Jim CIV OASN (EI&E), ODASN Environment
Subject: RE: DON PFC Strategy - Comments due 15 April

All,

As discussed during today's AFFF stakeholder meeting, DASN(E) would like comments on the draft PFC strategy within the next two weeks. Please send me any comments by COB Friday 15 April, and I will consolidate Navy comments and submit to DASN(E) on 18 April. Please coordinate internally with anyone I may have missed on distribution.

V/R,
Lindsay

-----Original Message-----
From: Mach, Richard CIV OASN (EI&E), ODASN (Environment)
Sent: Thursday, March 31, 2016 4:43 PM
To: Barclift, David J CIV NAVFAC LANT, EV; Berkoski, Daniel T CIV NAVSEA, SEA 05; Blodgett, Wayne CIV NAVFAC HQ, EV; Brant, Byron C CIV NAVFAC LANT, EV; Brown, Kim P CIV NAVFAC HQ, EV; Carlson, Margaret M CIV OASN (EI&E), OAGC (EI&E); Coghlan, Gunarti H CIV NAVFAC HQ, ENV; Corack, Jennifer M CIV NAVFAC Atlantic, EV; Duchnak, Laura S CIV NAVFAC HQ, BRAC PMO; Dumenigo, Mario O CIV NAVFAC HQ, EV; Frederickson, Joshua M CIV OPNAV, N45; Gamache, Christopher D CIV I&L, GF; Greek, Patricia Z CIV CNIC, N452; Hayes, Dan E CIV NAVFAC HQ, EV; Hellman, David H CIV NAVFAC HQ, BRAC PMO; Holmes, Wanda L CIV OPNAV, N45; Hunstad, Mary P CIV NAVSEA HQ, SEA 05; Laitila, Jeffrey P CIV NAVFAC MIDLANT, EV; Lansdale, Lawrence L CIV NAVFAC HQ, BRAC PMO; Nashold, Elizabeth A CIV NAVFAC MIDLANT, EV BLC; Nehm, Lindsay R CIV OPNAV, N45; Onyekanne, Chika LT CHINFO, OI-2; Porter, Christine H CIV CNIC HQ,

N45; Preston, Gregory C CIV NAVFAC HQ, BRAC PMO; RIESCHE, TIM G E5/HM2 00, 00; Rosen, Marc S CDR OLA, LA-63; Rudroff, Jim CIV OASN (EI&E), ODASN Environment; Runyon, Rex A CIV PA; Sadorra, Robert A CIV NAVFAC HQ, EV; Schirmer, Robert G CIV NAVFAC MIDLANT, EV; Taplin, Aundrea E CIV OASN (EI&E), OAGC EI&E; Turner, Misha GS13 I&L, LFL; Walker, Yvonne P. (CIV)
Cc: Ohannessian, Karnig H SES OASN EI&E; Mustain, Jennifer L CIV SES OASN (EI&E), DASN IF&B
Subject: DON PFC Strategy

All,

I am providing an update as to where we stand within DON regarding the many aspects of PFCs. As requested by ASN, I have been working with many/most of you to pull together all the moving parts related to PFCs. Attached is the latest version of a DON Strategy outline. I have incorporated/addressed preliminary input from USMC and N45. I have briefed DASN(E), DASN(I&F), and PDASN(EI&E) and added to the outline based on their direction. They support the proactive approach we have taken to date and the additional steps we will be taking in the future. As you will see, there are a number of places indicating needs and future DASN(E)/ASN(EI&E) policy/direction. Please start preparing for these pending actions and provide me feedback if you have suggestions on better ways to accomplish these efforts.

Since many things are moving and still in flux, I want to list some of the near term actions and steps moving forward as well as the status of some items for the future.
1.First, if there are new media or CODEL inquiries, please ensure chain of command review, with our office providing final approval on responses. We want to ensure accuracy, consistency, and alignment with our leadership's vision for the future. Once Need 1 in the attached is completed, there will be a simple place to retrieve previously approved responses and only "different" inquiries will need this level of review/approval.
2. I am meeting with NAVFAC next week to obtain assistance/support from an individual in their leadership development program to assist pulling many elements of this strategy together. Our goal is to get this well organized in a short time to allow efficient implementation by all.
3. The pending data call regarding where we have installations that have had no PFC sampling is new. We are likely going to send this request soon, so start preparing your folks to respond.
4. There are a lot of moving parts in the environmental restoration program (ERP). We are working closely with the ER,N and BRAC programs to identify the universe of our release sites and will be coordinating with USMC and CNIC to support this effort. This is going to lead to an increased number of sites and several more off-installation sampling events. We want to use the positive lessons learned from Fentress, Earle, Willow Grove, and Warminster as we press forward. This has played well with the regulators, communities, media, and CODEL.
5. BRAC is briefing CNIC next week and I will represent DASN(E) to answer any other questions ADM Smith might have about this strategy.
6. We are meeting with many of you next week to discuss the AFFF BMPs and phase out of PFOA/PFOS based AFFF. I know there is some concern that the plans in the attached go beyond the OSD directive. We are aware of that and our leadership thinks this is the right path. We want to move aggressively to ensure we eliminate the possibility of creating new release sites. We want to be prudent with our resources, but the cost of addressing one or two more releases will easily surpass the cost of material replacement or BMP implementation. Warminster and Willow Grove demonstrate that, with $19M spent to date on these two locations.
7. The Warner/Kaine response is awaiting SECNAV front office approval for release and we are standing by to see when they want a brief.

Thanks for all your hard work and support in these efforts.

VR,
Richard

Additional Technical PFC Comments

1. The generic use of PFCs is somewhat worrisome. RPMs need to understands PFCs are a large group of chemicals, not just the 6 sampled on the UCMR3 list. Since 'PFCs' now includes over 100 compounds - a general statement indicating 'recent research indicates over 100 PFCs (which are strictly anthropogenic) have been identified in the environment should be noted in the strategy.

2. Suggest the consideration for other routes of exposure (specifically eco [ingestion of animals with PFCs since they bioaccumulate]). BTAG is furiously working on establishing eco screening values. Maybe some sort of statement indicating 'As screening values are established for other routes of exposure, new guidance/policies will be established?' We have been able to 'fend' off other routes of exposure to date by simply stating Navy policy only allows me to address direct ingestion of drinking water by human consumption - but I'm pretty sure this will not be sufficient to address the Fentress community and BTAG in the near future.

3. Strategy should note that EPA is pushing to investigate metal plating facilities for PFCs, possibly including the potential 'PFCs' associated with the metal plating suppressants (that contain PFCs) that are assumed to be present in discharges, sludges, etc.

4. In regards to Fentress, the RPM has been repeatedly asked where the treatment systems (water treatment plant and wastewater treatment lagoon) sludges, filter backwash, etc have been disposed in the past (to see if these disposal areas would have contaminated groundwater/drinking water in another location). This is yet another reason that it is so important the RPM needs to completely understands the entire PFC CSM for the base (which includes contaminant source area, migration pathways, lithology, points of extraction, septic tank locations (on and off base) any treatment facilities, and ultimate disposal of sludges/backwash water from these treatment facilities, etc).

5. Recommend that the Navy's approach to monitor a residence if PFCs are detected below federal or state (P)Has should be changed for the following reasons:

    a. The level measurement of these compounds is in the parts per trillion which is extremely low. The criteria to monitor a location if below the (P)HA action level but above 25% of this level means we are looking at concentrations that are even lower and sometimes we may be taking action on spurious analytical results. In addition, to monitor (i.e. return to a residence to sample quarterly) means we may be elevating a concern for a resident when results are not indicative of a need for concern (i.e., we should perhaps look at this action from the resident's view point instead of the Navy's perspective of being protective).

    b. The PFCs we are looking for are very common in the environment and their presence in a resident's drinking water may not be directly attributable to a Navy source. If we find PFCs that are at low concentrations, we may be monitoring a source local to the resident's well and not part of a Navy-sourced plume. The decision to return to sample a residence should be deferred until the site source investigation progresses and the CSM is built, thus allowing for informed decisions as to the area to monitor.

6. The science of PFC fate and transport is evolving and it is unclear if some PFCs detected in groundwater are directly attributable to AFFF chemistry (e.g., PFNA). Recommend a desk top study of literature to allow making informed DON decision(s) as to which PFCs are directly related to AFFF chemistry and then action decisions can be made on specific compounds.

7. As the States and EPA move forward with looking at the full suite of PFCs, it may be beneficial to know which PFCs are directly attributable to past use of the foam and thus are likely Navy-sourced. Such a study may (or may not) prevent the expenditure of Navy funds in addressing a contaminant not related to Navy actions.

Fluorinated Compounds: Filtering through the noise and emotions

Rhonda Stone
Heather Polinsky
Jeff Burdick
Joe Quinnan
Suthan Suthersan

June 29, 2016

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Learning Objectives

- Overview of the PFAS issue to provide the knowledge needed to avoid impulsive reactions
- Understand how PFAS reacts in the environment to ensure the most appropriate sampling and analytical methods and treatment technologies are selected
- Have the information needed to allow you to focus on your mission and direct your program going forward.

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Overview of the PFAS Issue

With knowledge you can avoid impulsive decisions

PFAS in the Headlines

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Horsham Water and Sewer Authority Takes 2 Wells Out of Service Due to Detection of Perfluorooctane Sulfonate (PFOS) Above Provisional Health Advisory Level

Two of the Authority supply wells, Well No. 26 and Well No. 40 were recently found to have PFOS above the PHA level (detected at 0.7 ppb and 1.0 ppb respectively). PFOS was also detected in other Authority wells but not above the PHA level. **After consulting with DEP, the Authority decided to take Well Nos. 26 and 40 off-line.**

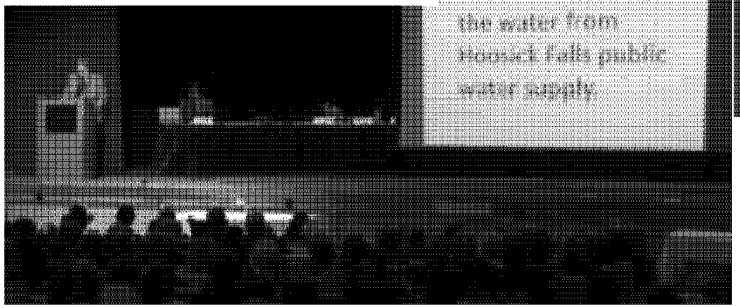
PUBLIC NOTICE FROM YOUR WATER AUTHORITY
FORMER NASJRB WILLOW GROVE, PA
FORMER NAWC WARMINSTER, PA
HORSHAM AIR GUARD STATION, PA

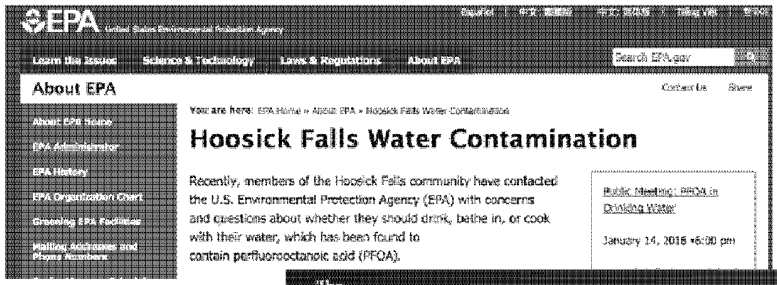
EPA has changed the limit for PFCs to a health advisory with lower long-term limits. Due to this change the Warminster Authority has removed three additional wells from production. All three wells were currently tested to meet this new standard but at one time tested close or over the limit. Three previous wells taken out of service are under construction for carbon filtration to remove PFC's. We continue to meet the regulatory standards issued by EPA for PFCs.

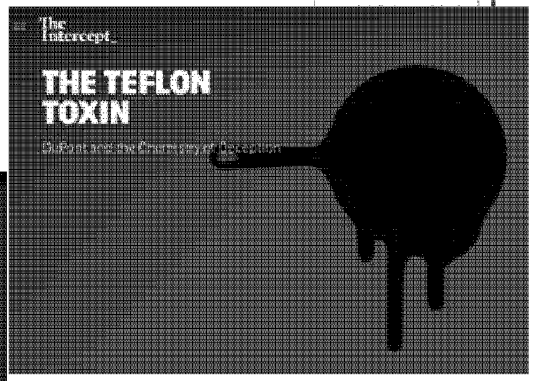
Contact the appropriate military service representative or visit these websites:
http://www.bracpmo.navy.mil/brac_bases/northeast/reserve_base_willow_grove.html
http://bracpmo.navy.mil/brac_bases/northeast/former_warfare_center_warminster.html
http://www.111attackwing.ang.af.mil/
Navy: Mr. Willington Lin, BRAC Environmental Coordinator; 4911 South Broad Street, Philadelphia, PA 19112. Phone (215)897-4900 or e-mail willie.lin@navy.mil
Air National Guard: Mr. Keith Freihofer, Environmental Restoration Program Manager; 3501 Fetchet Ave - Shepperd Hall, Joint Base Andrews, MD 20762-5157. Phone (240)612-8762

The FDA Just Banned These Chemicals in Food. Are They the Tip of the Iceberg?

FDA banned three toxic food packaging chemicals and is considering banning seven cancer-causing food flavoring chemicals, but food safety advocates say the process highlights flaws in the system.

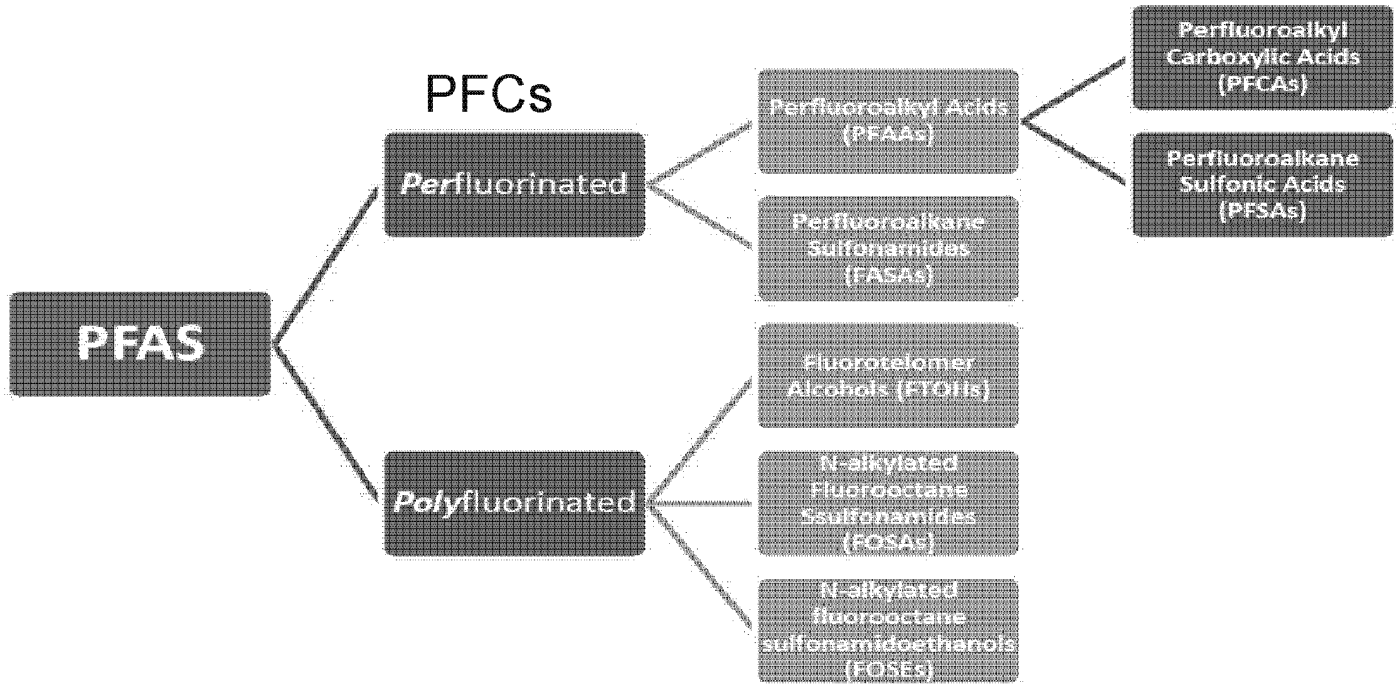






The Emotional State of Heightened Awareness & Accelerated Activity

Some call it “PFAS” and others “PFCs”…



- PFAS include PFOS, PFOA and approximately 6,000 fluorinated compounds
- AFFF contains > 200 PFAS compounds

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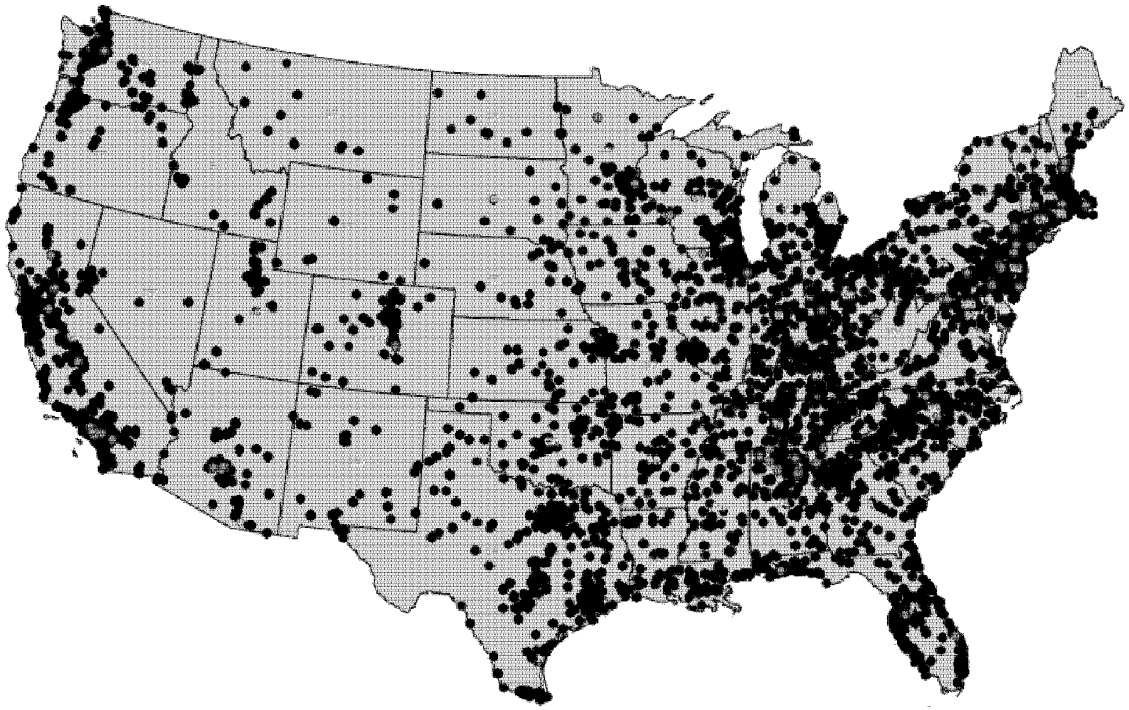
Magnitude of Problem



USEPA – Unregulated contaminant monitoring rule #3,UCMR3 2013-15

63 water utilities with PFOS and/or PFOA detections above Health Advisory

Health Advisories for long term exposure to PFOS and PFOA in drinking water (May 2016):

- 70 ppt combined

Previous Provisional Health Advisories for short term exposure (2009)

200 ppt PFOS

400 ppt PFOA

Detected in ~ 2% of public water supplies

Standard has dropped by an Order of Magnitude

Challenges Facing DOD

- Regulatory drivers
- Budget constraints
- Need for standardized guidance
- Public outcry
- Congressional pressure
- Impact to 2018/2021 DERP Goals
- Inconclusive and evolving information

What are YOUR Priorities?

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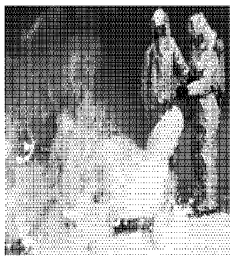
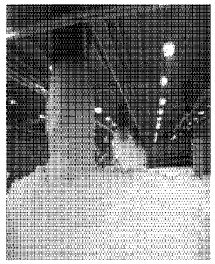
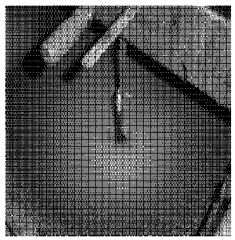
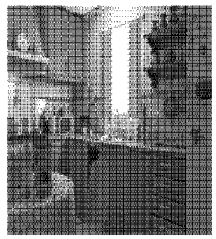
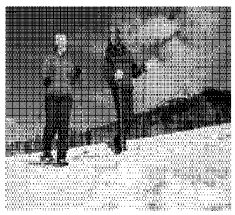
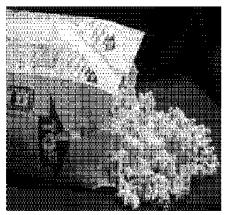
PFAS/PFOA Ubiquitous in the Environment

Surface Treatment

- Carpet Protector
- Fabric/upholstery protector
- Apparel and leather protector
- Protective products for consumer applications

Paper and Packaging Protectors

- Food packaging
- Paper products

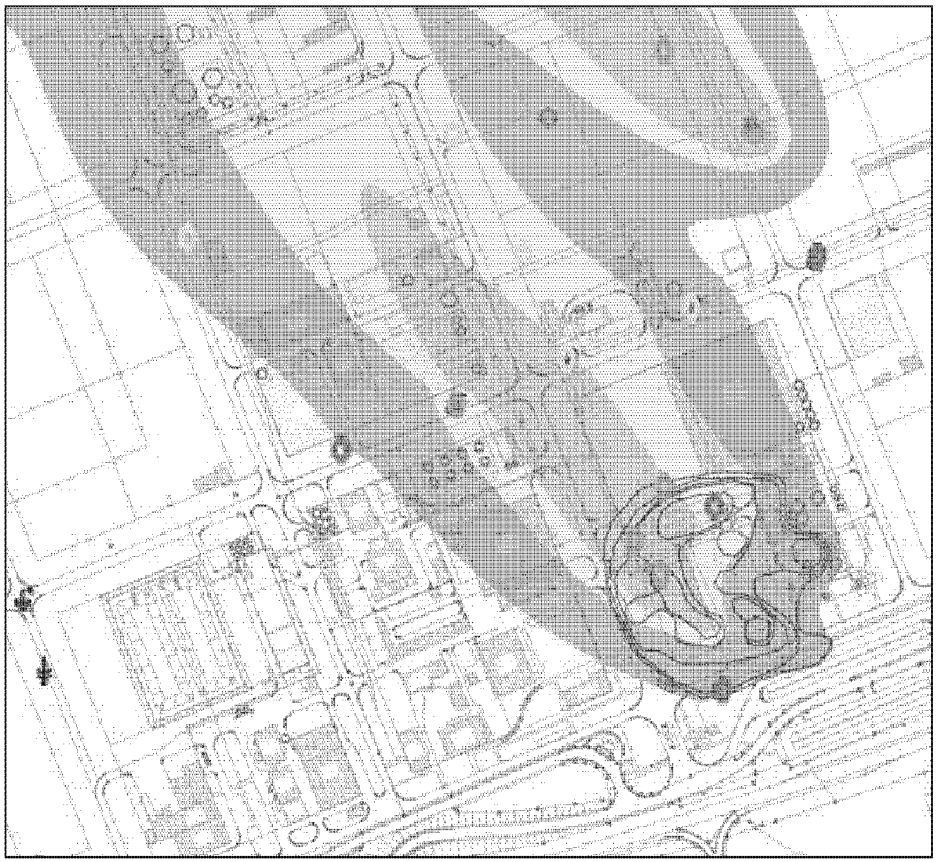







Performance Chemicals

- Fire Extinguishing foam concentrates
- Mining and oil surfactants
- Electroplating and etching bath surfactants
- Household additives
- Chemical intermediates
- Coatings and Coating Additives
- Carpet spot cleaners
- Insecticides raw materials

Many Potential Sources

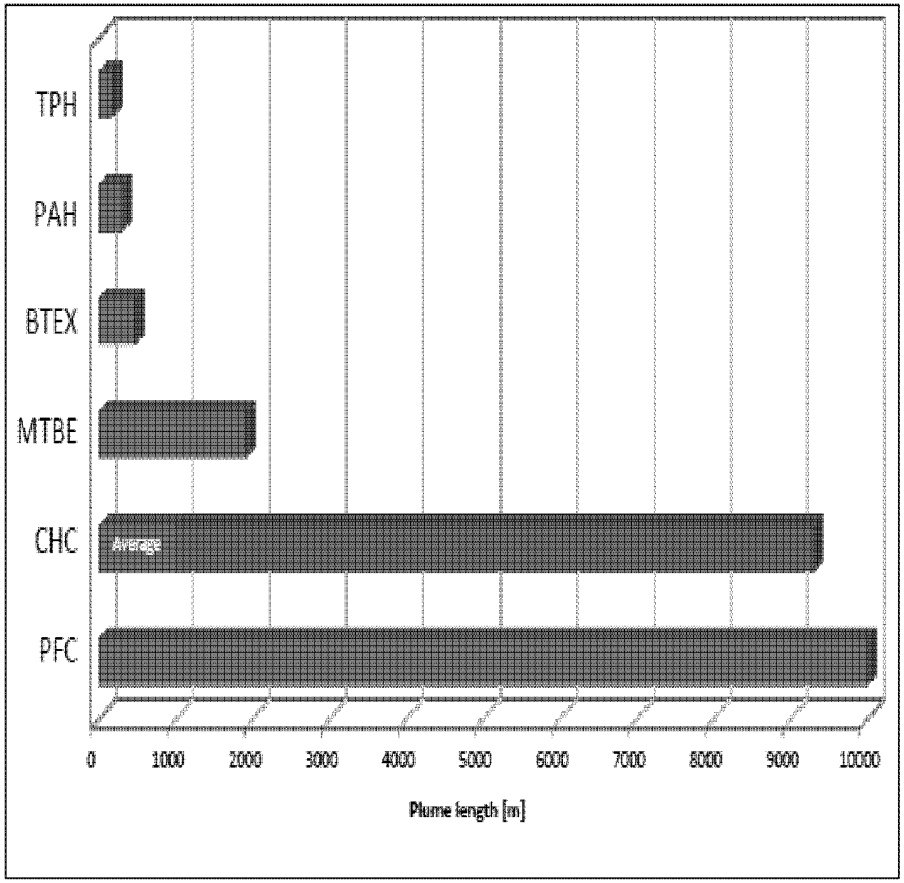
- Fire Training Areas
- Fire Stations
- Airfields/Airports
- Hangars
- Landfills
- Wastewater
- Plating
- Photo development



Chemical Properties and Implications

PFAS plumes are generally longer

- High solubility
- Low log K_{oc}
- Recalcitrant
- Mostly Anionic



Chemical Properties	PCB (Arochlor 1260)	PFOA	PFOS	TCE	Benzene
Molecular Weight	357.7	414.07	538	131.5	78.11
Solubility (@20-25°C), mg/L	0.0027	3400 – 9500	519	1100	1780
Vapor Pressure (@25°C), mmHg	4.05×10^{-5}	0.5-10	2.48×10^{-6}	77.5	97
Henry's Constant, atm-m^3/mol	4.6×10^{-3}	1.01×10^{-4}	3.05×10^{-9}	0.01	0.0056
Log Koc	5 – 7	2.06	2.57	2.473	2.13

Persistence and mobility can lead to large plumes

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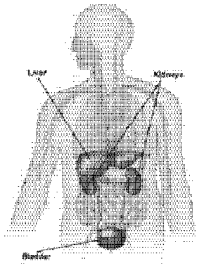


PFAS: Health Effects a Debate over Correlation and Causality

EXPOSURE

- Exposure is most likely via ingestion of contaminated food or water
- Breast milk
- Air
- Dust
- Skin contact with various consumer products
- Carpets treated with PFAS can be an important source of exposure for children

DISTRIBUTION

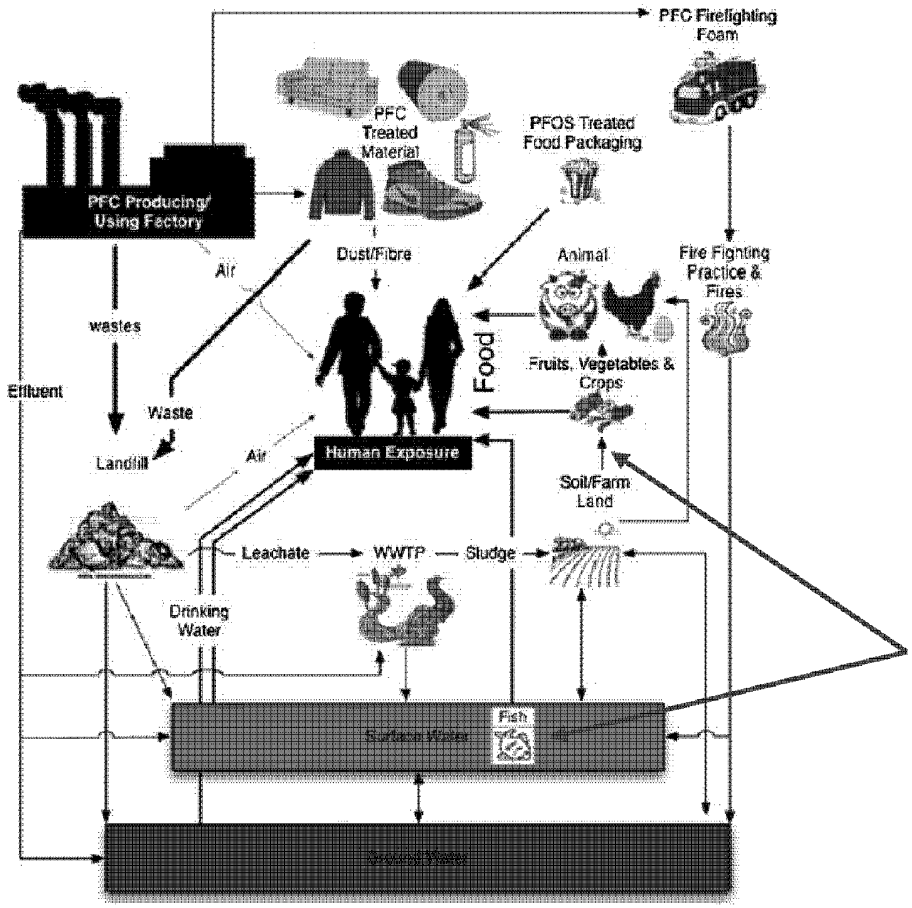
- PFAS bind to proteins (not to lipids / fat)
- Highest concentrations in blood, liver, kidneys, lung, spleen and bone marrow
- PFOS and PFOA have bioaccumulative properties
- Shorter chain PFAS have generally a lower bioaccumulation potential, although there may be some exceptions.

ELIMINATION

- Elimination of PFOS and PFOA from the human body takes some years, whereas elimination of shorter chain PFAS are in the range of days
- Apart from chain length, blood half-lives of PFAS are also dependent on gender, PFAS-structure (branched vs. straight isomers), PFAS-type (sulfonates vs. carboxylates) and species.
- Elimination mainly by urine.
- Carcinogeneity “suggestive” (USEPA 2016)

Data on toxicity on other PFAS compounds than PFOS and PFOA is meager and inconsistent.

What's Driving the PFAS Standards?

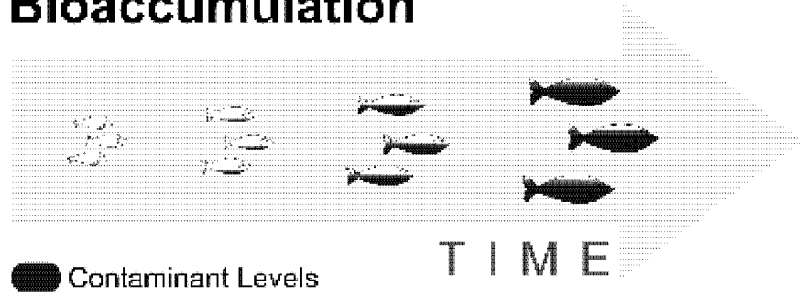


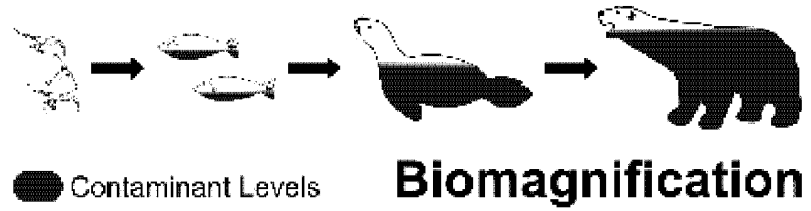
The PFAS web

Oliaei et al. Environ. Sci. Pollut Res (2013) 20: 1977-1992

- USEPA has selected RfD for PFOS and PFOA of 20 ng/kg bw/day (May 2016)
- European Food Safety Authority (2008):) established a TDI for PFOS and PFOA of 150 ng/kg bw/day and 1.500 ng/kg bw/day

Bioaccumulation





Multiple exposure pathways for PFAS compounded via bioaccumulation / biomagnification

Will Europe's Trends Influence the US?

Europe has been regulating PFAS for more than a decade

- Sweden's standard is sum of 12 PFAS compounds < 100 ppt
- Denmark's standard is sum of 7 PFAS < 90 ppt
- Germany, UK and the Netherlands have standards in 100's ppt

- European proposed surface water standard is even lower, 0.65 ppt for inland waters, due to bioaccumulation in fish

Why so low?

- PFOS and PFOA are classified as persistent, bioaccumulative and toxic
  - PFOS banned globally under Stockholm Convention
  - PFOA voluntarily phased out of manufacturing, replaced by shorter-chained PFAS
- On-going evaluation of shorter-chained PFAS health effects

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PFAS In the Environment

Choose the Right Techniques to Make Effective Decisions

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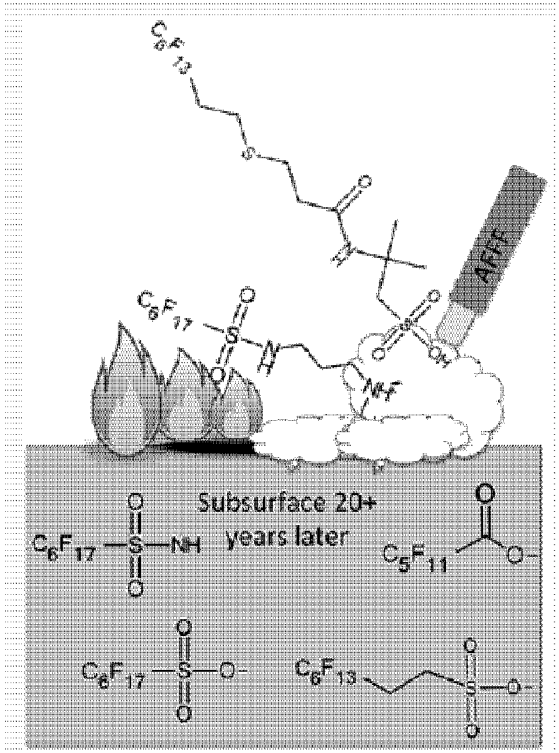
Are the current analytical techniques (EPA 537) adequate?



Are you getting a complete picture?

Analysis by EPA Method 537

- Offered by a number of laboratories including TestAmerica, Pace Analytical, ALS Global, SGS Accutest, and BSK Associates
- Sample costs range from ~$250 to $550 per groundwater sample and $250 to $350 per soil sample
- Analysis for selected perfluorinated alkyl acids (PFAAs)
  - Number of analytes reported for groundwater ranges from six analytes for the UCMR3 list up to 23 analytes using an expanded list
  - Number of analytes reported for soil ranges from 6 for the UCMR3 list to 16 analytes using an expanded list
  - Expanding the list of compounds that could be analyzed by Method 537 is limited by the availability of standards
- Detection limits for groundwater range from 2 and 20 nanograms per liter (ng/L).
- Detection limits for soil range from 0.2 micrograms per kilogram (µg/kg) to 25 µg/kg.

Other sample analyses are needed for site characterization…

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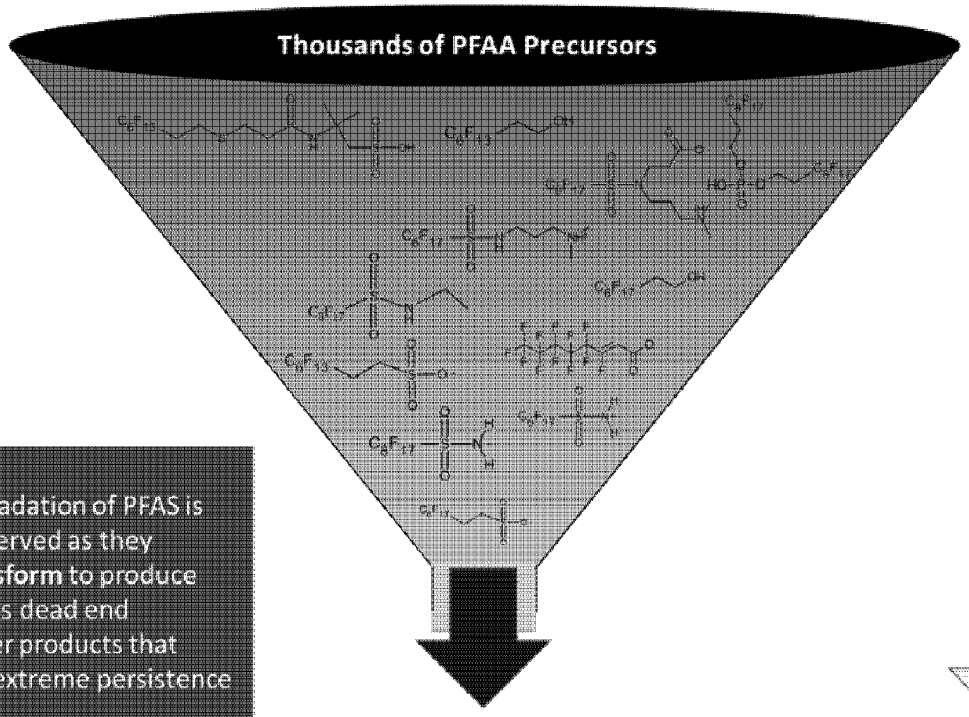
Aerobic Biotransformation of Precursors – Implications for Risk, Fate & Transport and Remediation

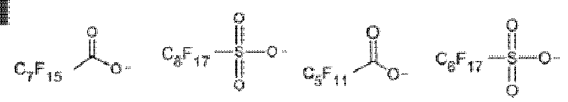


All Polyfluorinated / PFAA Precursor Compounds in Commerce (*"Dark Matter"*)

Hundreds of Common Intermediate Transformation Products

Approximately 25 PFSAs, PFCAs, PFPAs –collectively termed PFAA's

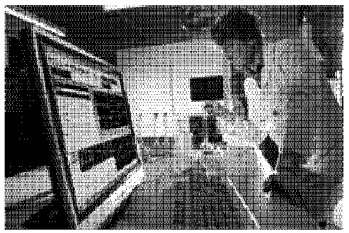
Biodegradation of PFAS is not observed as they **biotransform** to produce PFAA's as dead end daughter products that exhibit extreme persistence

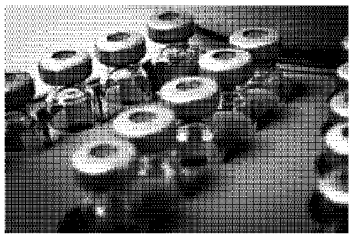


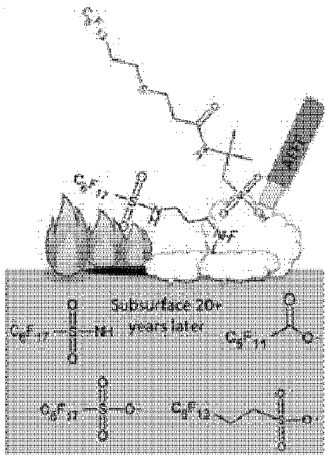
Dead-end PFAS compounds do not biodegrade –i.e. mineralize

Expanding analytical tool box for precursors

- Total oxidizable precursors (TOP) Assay –
  - Pretreatment of sample prior to LCMSMS
  - Detection limits to ~ 2 ng/L
- Particle-induced gamma emission (PIGE) Spectroscopy
  - Separation of organofluorine compounds + total fluorine analysis (analogous to TPH for hydrocarbons)
  - Detection limits to ~ 2 ug/L F
- Adsorbable organofluorine (AOF)
  - Process with activated carbon and subsequent analysis by CIC
  - Detection limits to ~ 1 ug/L F







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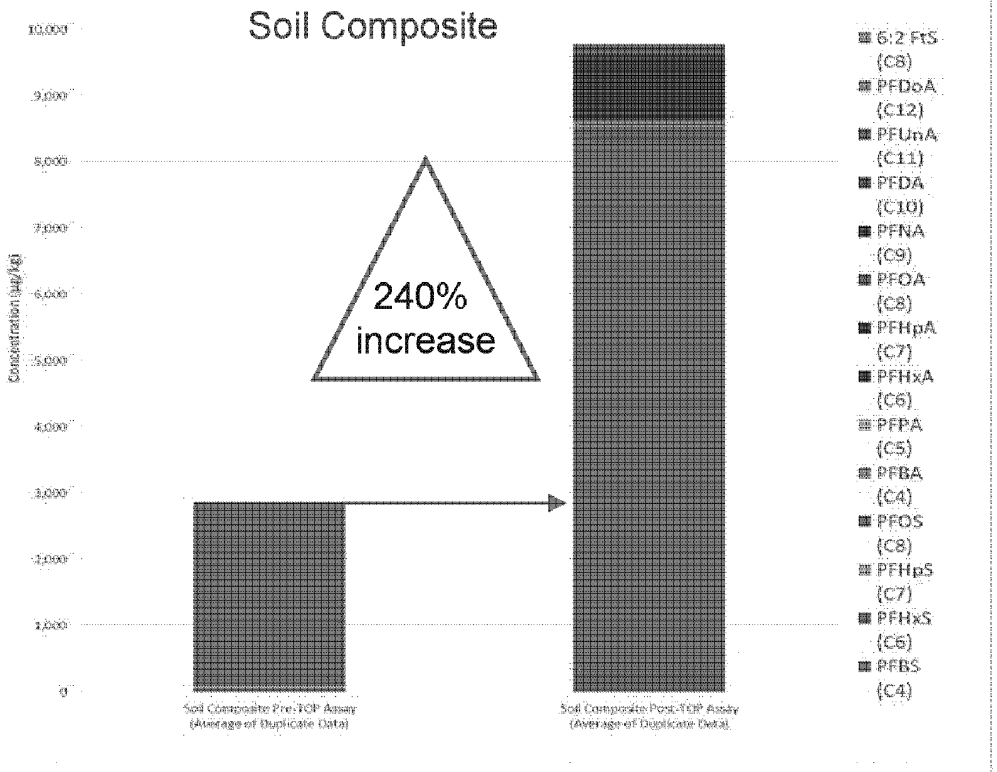
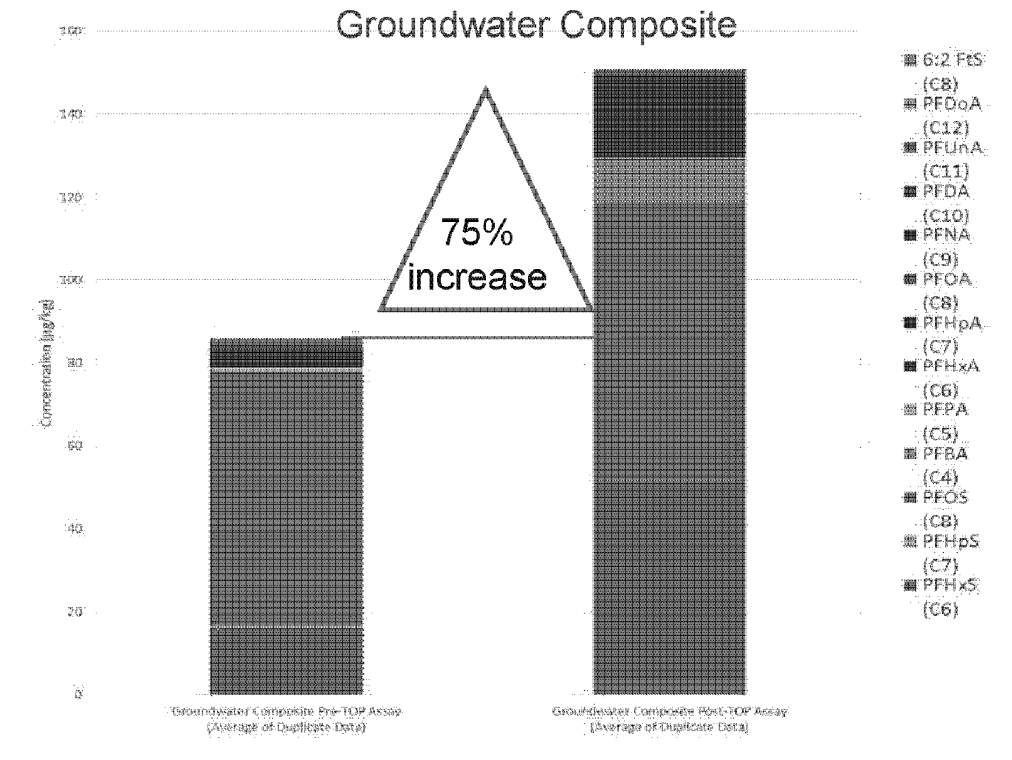
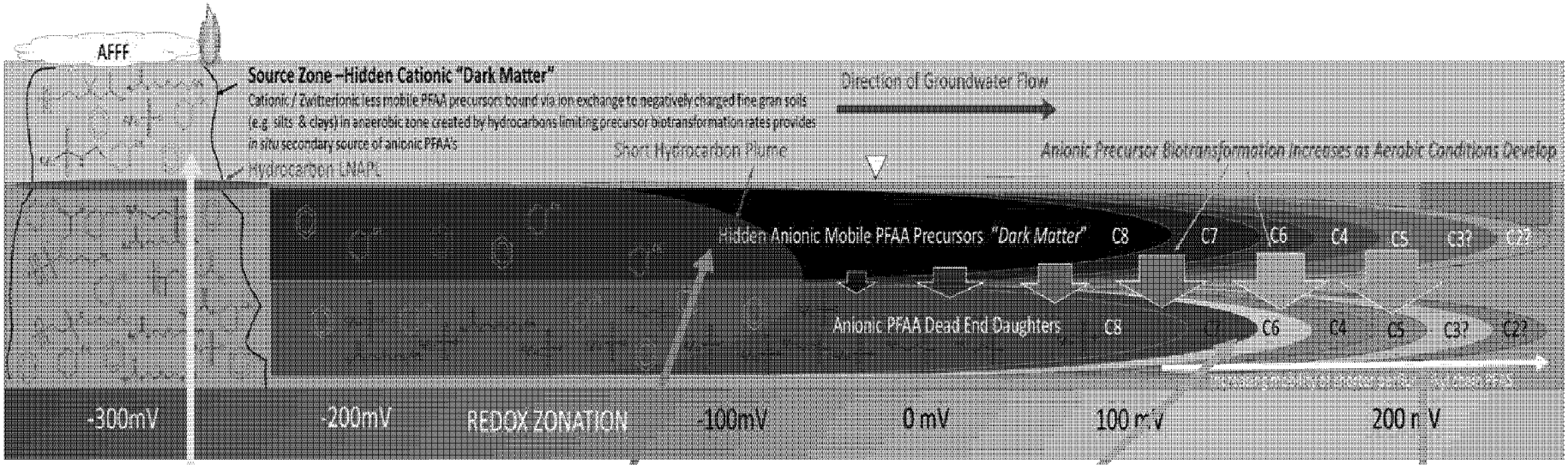
EPA Method 537 Underestimates the Potential Source Term





Hidden Mass or "Dark Matter" – Implications for Risk, CSM, Fate and Transport and Remediation

Conceptual Site Model - AFFF Fire Training Area



Source zone – hidden cationic and cation dominated zwitterion "Dark Matter" in more anaerobic environment

Mobile zone – hidden anionic and anion dominated zwitterions (more mobile) PFAA precursors, "Dark Matter"

Anionic precursor biotransformation increases as aerobic conditions develop downgradient of hydrocarbon plume

Increasing mobility of shorter perfluoroalkyl chain PFAS

CSM is critical in framing long term liability/strategy

US00022349

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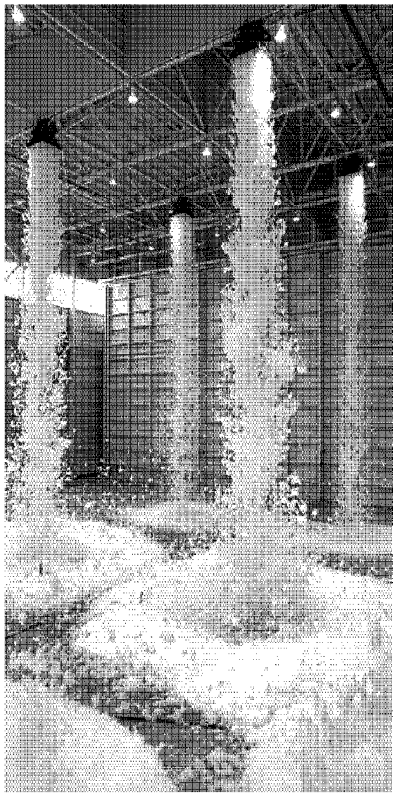
Understand Your Risks – Make Informed Decisions

- Fire Training Center for AFFF testing and trials since 1970's.
- AFFF/PFAS sprayed daily/9 months/year for 30 to 40 years.
- 3,000 foot benzene plume in groundwater /PFAS presence in soil/groundwater.
- Potential for Significant Brand- PR and 3rd party Liability



Receptor Survey/Vulnerability Assessment – Vapor Intrusion (VI) assessment (BTEX) for off site properties; >80 wells within 1 mile of site.

Source (FTA) and Plume Delineation – Real time delineation using mobile labs; aquifer testing to assess transport and off site risk. Assessment of PFAS in soil and groundwater and regulatory reporting/negotiation.

Source Remediation Design/Implementation – Client desires a rapid delineation and source excavation during Fall season business shutdown. PFAS disclosure could increase risk/cost ($2M to $40M). Potential for alternative remedies/Arcadis R&D.

PFAS Groundwater Delineation/Remediation – To be determined based on receptor survey. Plume could be more than a mile long.

Approach Not Always As It First Appears

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Field Sampling Techniques: What are the Right Ways to Sample

PFAS Sampling Guidelines

- United Nations Environment Programme (UNEP), Division of Technology, Industry and Economics. 2015. *PFAS analysis in water for the Global Monitoring Plan of the Stolkholm Convention, Set-up and guidelines for monitoring.* April.
- Government of Western Australia, Department of Environmental Regulation. 2016. *Interim Guideline on the Assessment and Management of Perfluoroalkyl Substances (PFAS), Contaminated Sites Guidelines.* February.
- Environmental Fate and Effects of Poly- and Perfluoroalkyl Substances (PFAS). 2016. CONCAWE (European Industrial Consortium)
- Statement of Requirements for FPAS Site Assessments. 2016 Public Services and Procurement Canada & Transport Canada.

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PFAS Water Sampling Protocol

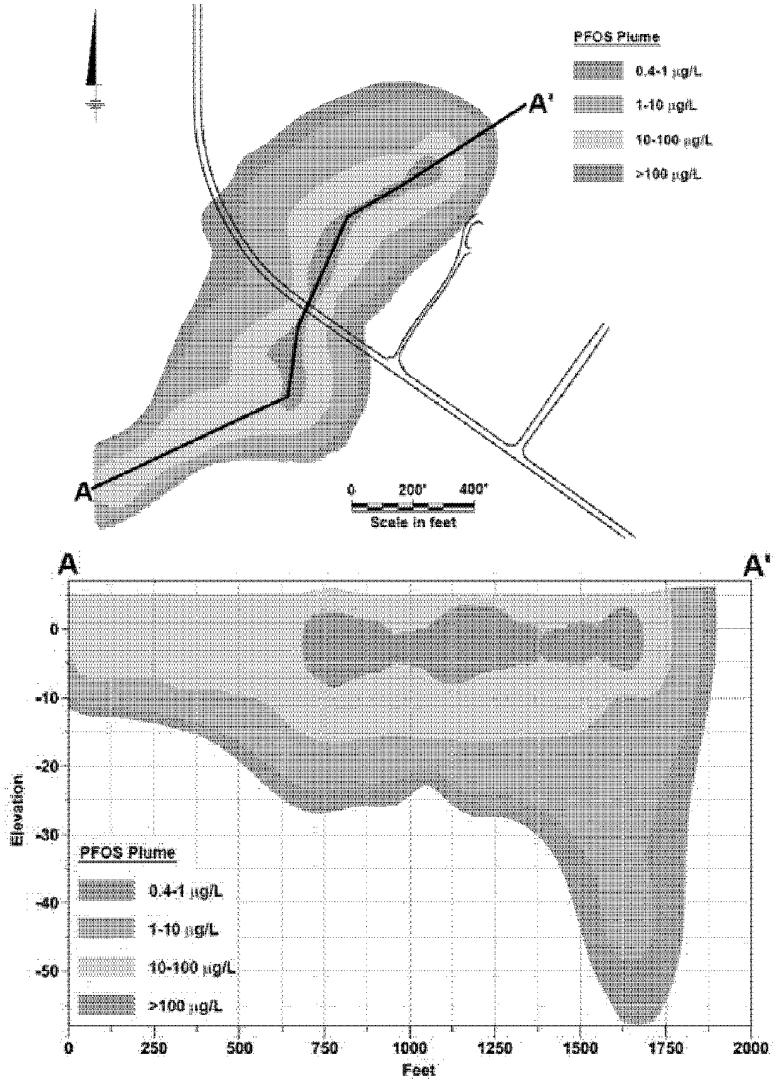
- Precautions for personal field gear including no water proof or stain-treated clothing during sampling event
- Precautions for field personnel to limit contact with certain food products
- Maintain clean work area, consider dedicated plastic sheeting to prevent contact with ground
- Use high density polyethylene (HDPE) bottles fitted with HDPE liner screw cap only
- Use clean hands techniques – use nitrile gloves at all times and don a fresh pair for multiple steps of sampling process
- Avoid markers, use pen or pencil.
- Decontamination procedures include Citranox® cleaning solution, laboratory-provided, "PFAS-free" water, and methanol.
- Include collection of field reagent trip blank to evaluate potential for cross contamination to occur

High Resolution Site Characterization

Cape Canaveral Air Force Base

- Completed transects of hydraulic profiling tool to map permeability
- Vertical aquifer profiling to map PFOA and PFOS concentrations
  - Fixed lab EPA method 537
- Incremental sampling to assess sediment impacts due to discharge

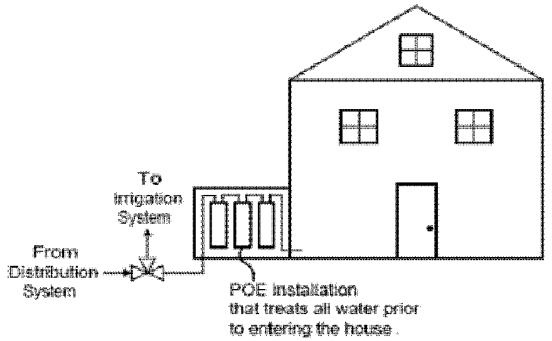
- Developing mobile lab capability
  - Real-time EPA Method 537
  - Adaptive delineation
  - Leverage advantages/lessons learned from solvents



If you find the Mass Flux you can target the remedy

Sampling Considerations for PFAS Point of Entry Treatment (POET) System

- Review state requirements for monitoring and reporting performance of POET systems
- Influent sampling should focus on characterizing any temporal changes in contaminant concentrations that could impact treatment requirements and breakthrough
- Effluent sampling should focus on confirming that treatment goals are met and water produced is protective of public health
- Effluent sampling can also be used to characterize and optimize treatment system operation
- Frequency and exact sample location will depend on treatment system configuration, regulatory requirements, and treatment objectives



Hoosick Falls, NY

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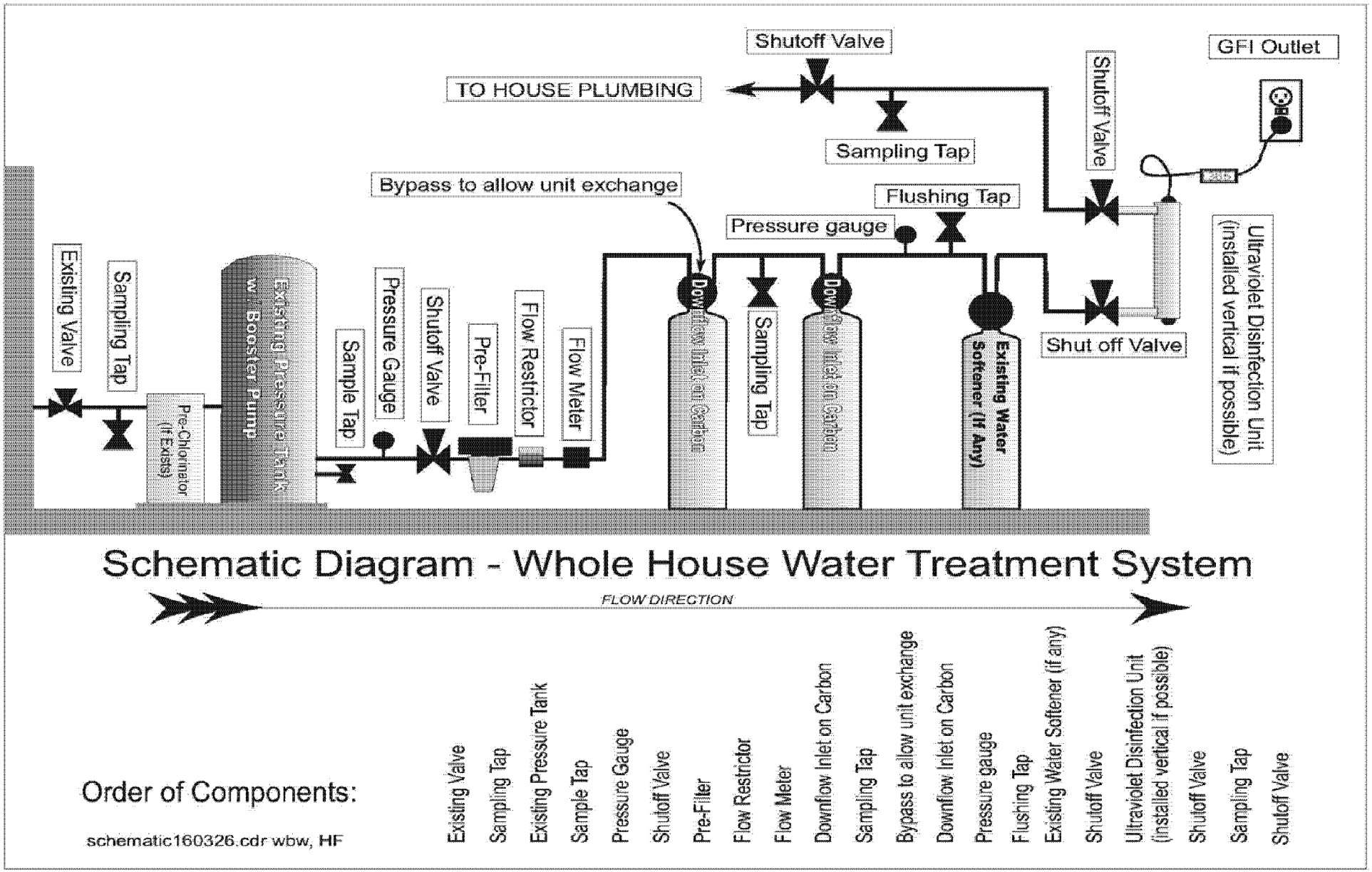

Hoosick Falls, NY
POET Sampling Plan

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System PFOA Concentration	Sample Frequency	Analysis	Sample Locations	QC Samples	QC Sample Frequency
Greater than 70 ppt	Quarterly	PFOA	PRE MID POST	FD MS/MSD	Every 20 Samples (5%)
	First Visit	TOC	PRE		
	After Each GAC Canister Replacement	METALS	POST		
40 – 70 ppt	Semi-Annually	PFOA	PRE MID POST	FD MS/MSD	Every 20 Samples (5%)
	First Visit	TOC	PRE		
	After Each GAC Canister Replacement	METALS	POST		
Less than 40 ppt	Annually	PFOA	PRE MID POST	FD MS/MSD	Every 20 Samples (5%)
	After Each GAC Canister Replacement	METALS	POST		

Tools to Optimize the POET Sampling Program

Bench tests to characterize POET performance based on site-specific water quality

Review full-scale sampling data for trends and potential to reduce sampling frequency

Provide redundancy in treatment to assure adequate contaminant removal while reducing sampling burden.

Arcadis has applied these tools at a diverse range of POET systems to develop sampling programs that are protective of public health, while taking into account a reasonable frequency of sampling.

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Getting ahead of the issue: Take Actions Now to Shape the Future

Drinking Water
Environmental Remediation

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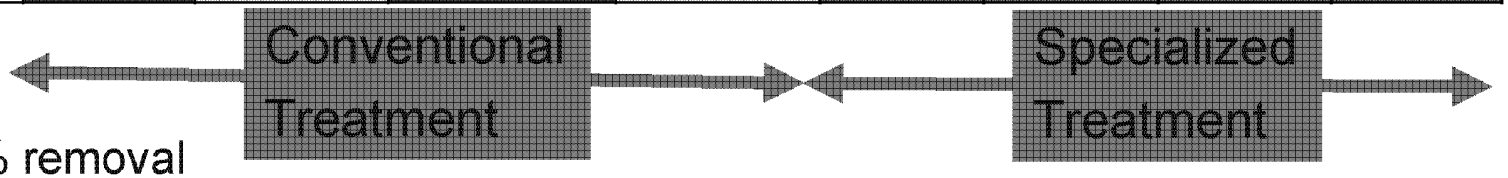
Demonstrated Drinking Water Treatment Options

Compound	M.W. (g/mol)	Aeration	Coagulation Dissolved Air Floatation	Coagulation Flocculation Sedimentation Filtration	Conventional Oxidation (MnO_4, O_3, ClO_2, CLM, UV-AOP)	Anion Exchange	**Granular Activated Carbon**	**Nano Filtration**	**Reverse Osmosis**
PFBA	214	assumed	assumed						
PFPeA	264								
PFHxA	314								
PFHpA	364								
PFOA	**414**								
PFNA	464					assumed	assumed		
PFDA	514					assumed	assumed		
PFBS	300								
PFHxS	400								
PFOS	**500**								
FOSA	499						assumed		assumed
N-MeFOSAA	571	assumed				assumed	assumed	assumed	
N-EtFOSAA	585					assumed	assumed	assumed	



Legend

- > 90% removal
- > 10%, < 90% removal
- < 10% removal
- unknown

After Dickenson and Higgins, 2016. Treatment mitigation strategies for poly- and perfluoralkyl substances, Water Research Foundation

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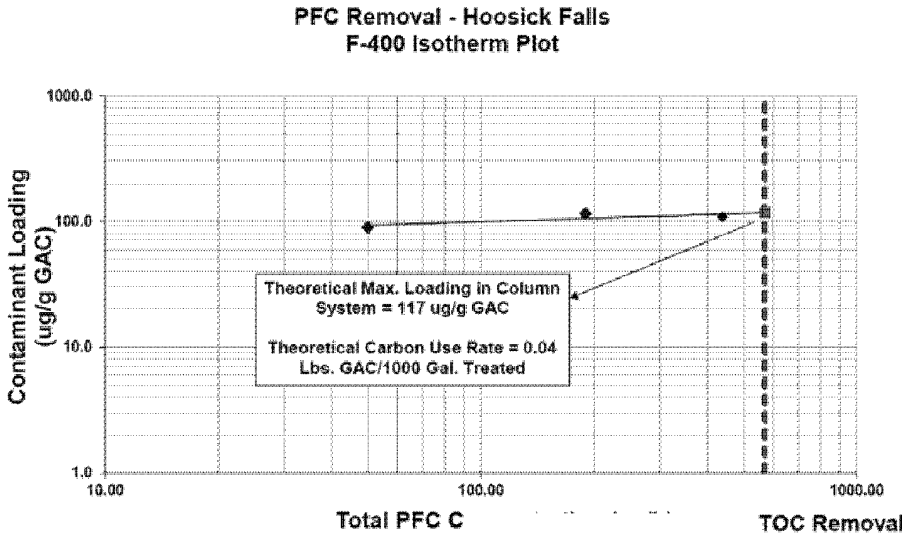
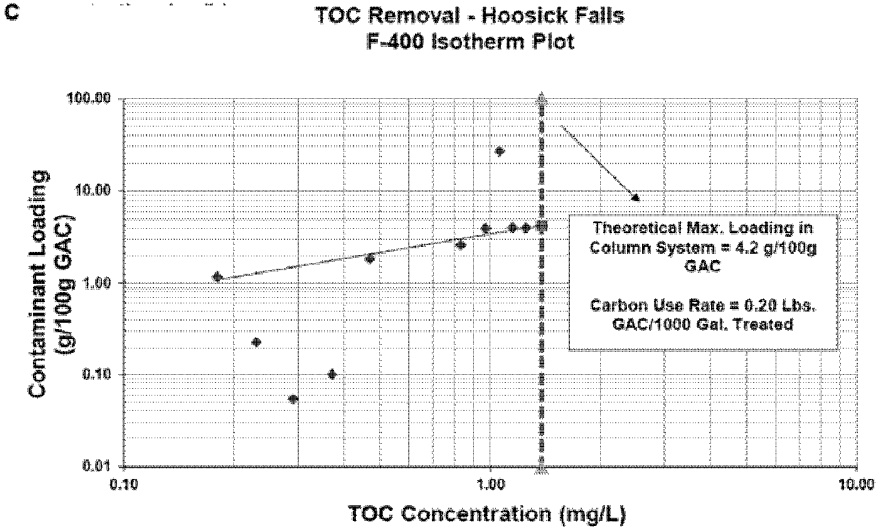
Current Water Treatment Options for PFOA and PFOS Removal

Treatment Strategy	Key Considerations
Granular activated carbon (GAC)	• GAC has been installed at multiple facilities over the past decade for PFOA removal from water supplies • Minimal liquid residual wastes • Spent carbon requires re-activation / disposal
Reverse Osmosis (RO) or Nanofiltration (NF)	• Full-scale applications for PFAS are limited • May reject a broader suite of PFAS • Generates a concentrate stream containing PFAS at higher levels than in source water
Ion Exchange	• Only removes PFOS, not PFOA • Regeneration??

GAC works today for PFOS & PFOA today, but can we do better?

GAC can be 80X more expensive for PFOS/PFOA than BTEX





- Column testing required determine GAC needs to treat PFAS
- GAC requirements are site specific
  - PFAS mixtures
  - Competition from
    - TOC from groundwater or surface water
    - Other contaminants

Need to Keep on OPTIMIZING

Continued Investment Is Needed

Short Term: Optimize GAC

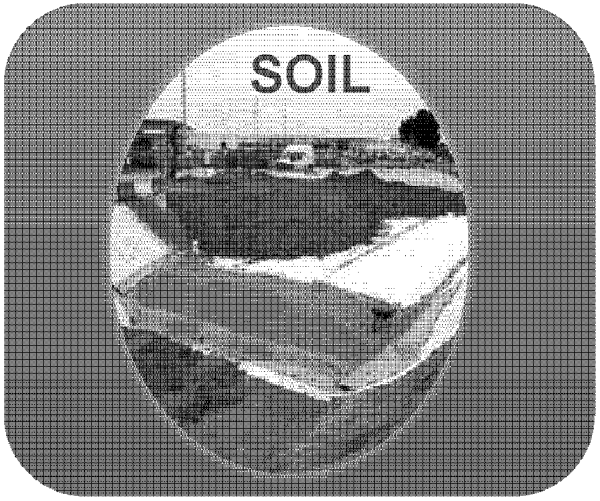
- Rapid small scale column testing (RSSCT) and TOP Assay to understand long-term cost and treatment requirements
- Alternative to high temperature regeneration - ScisoR
- Treatment train –AIX or FluorAdd

Long Term: Broad spectrum capability and reduced cost

- Treatment train technology
- Absorbing media and regenerable media
- Destructive treatment processes for RO/NF concentrates (ScisoR)
- Destructive treatment processes

In the long-term the greatest life-cycle reduction will be managing the source

Soil and Groundwater Remediation for PFAS



Excavation/disposal

Capping/containment

High-temperature incineration

Solidification/stabilization

No final solution; concentrate in another phase (no degradation)

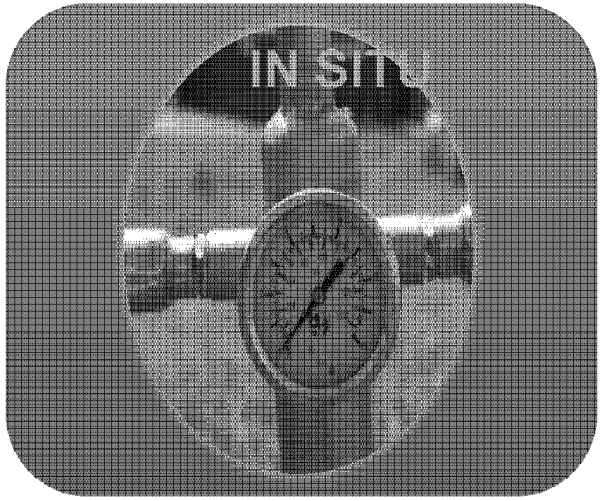
Granular activated carbon

Ion exchange resins

Reverse osmosis / nanofiltration

Other adsorbents

Low sorption of PFAS → higher GAC consumption → high replenishment/regeneration cost



Potentially effective evolving technologies

Combine various oxidants and catalysts

Nucleophiles, reductants, oxidants (ScisoR)

US00022364

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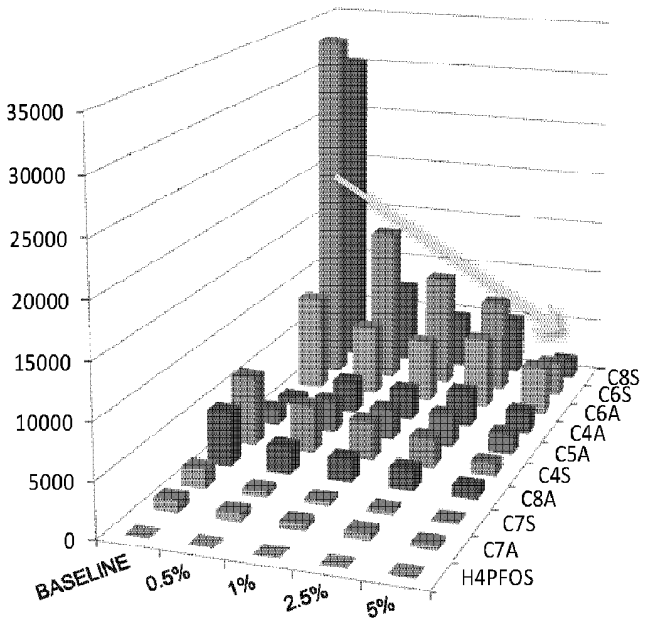
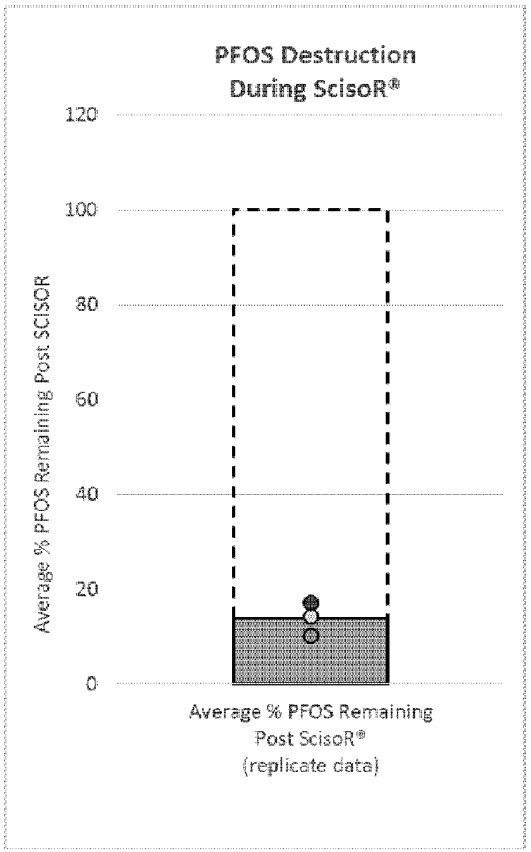
Arcadis' Patented Chemical Oxidation Method to Degrade PFAS

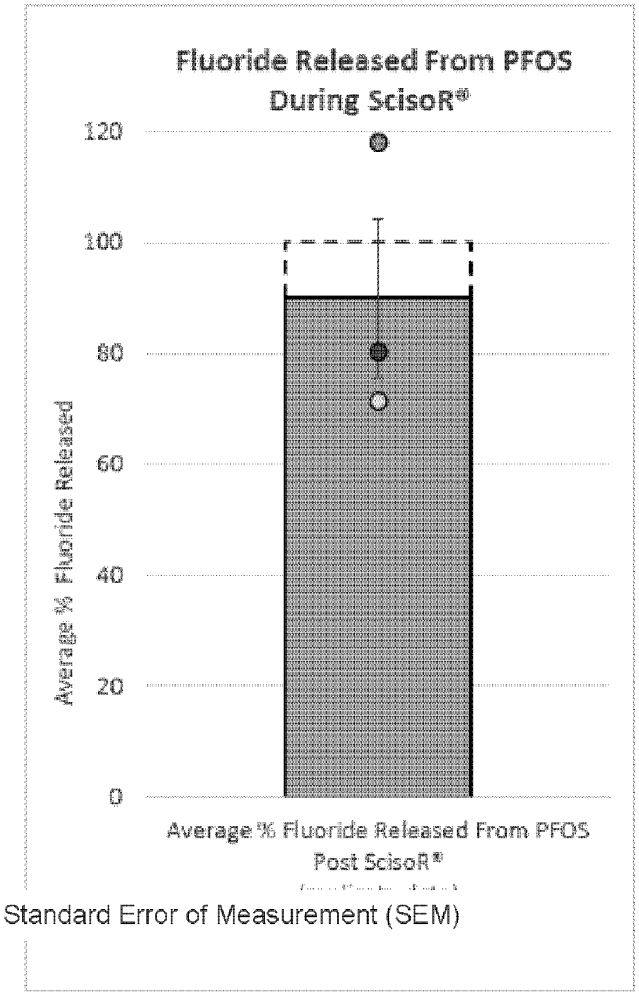


- Destruction of PFAS by chemical oxidation/reduction
  - Effective at ambient temperature
  - Soluble reagents can be injected or mixed with impacted soil and groundwater
- In situ remediation of AFFF impacted source areas
- Testing ability to treat waste/stockpiled AFFF
- Regeneration of support media (like ion exchange resins and other absorptive media) to destroy PFAS on site

ScisoR® bench scale data shows promise. Now being field tested

ScisoR Bench Scale: 90% PFOS Destruction with Mass Balance





Replicate Data. Error bars are % Standard Error of Measurement (SEM)

- 10 mg/L PFOS starting concentration
- 3 replicate data sets
- 83 to 90% PFOS destruction after 14 days
- 71% to 118% fluoride released from PFOS during SCISOR
- Overall fluoride mass balance (remaining fluoride in PFOS + fluoride released to solution)
  - 86% to 126% of theoretical
- All treated samples were blind spiked with 10 mg/L fluoride
  - 80% to 99% spike recovery
- Spike analyses demonstrate ion measured is fluoride, results are quantitative
- Longer reaction times and repeat applications of ScisoR will cause complete destruction of PFOS

Useful Graphics

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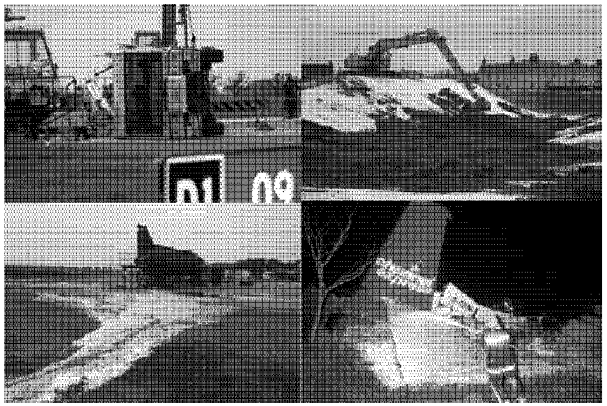
Channel Islands, State of Guernsey

PFOS Management Strategy



Persistent bio-accumulative perfluorinated compounds in the airport's firefighting Aqueous Film-Forming Foam (AFFF) were identified in surface waters which were being used as a primary source of the Island's drinking water supply. In 2009 Arcadis was commissioned to assist the State of Guernsey with a strategy to manage the risk to human health and the environment.

Our Approach

- Desk Based Review & Preliminary Risk Assessment
- Intrusive Assessments and Monitoring
- Fate & Transport Modelling
- Management/Remediation Strategy
- Interim Emergency Response Measures
- Implementation of Remedial Management Strategies

Concurrent Phases to Manage and Mitigate Risk

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Getting ahead of the issue: Case Studies

Drinking Water: Hoosick Falls, NY
Best Management Practices: AFFF Replacement

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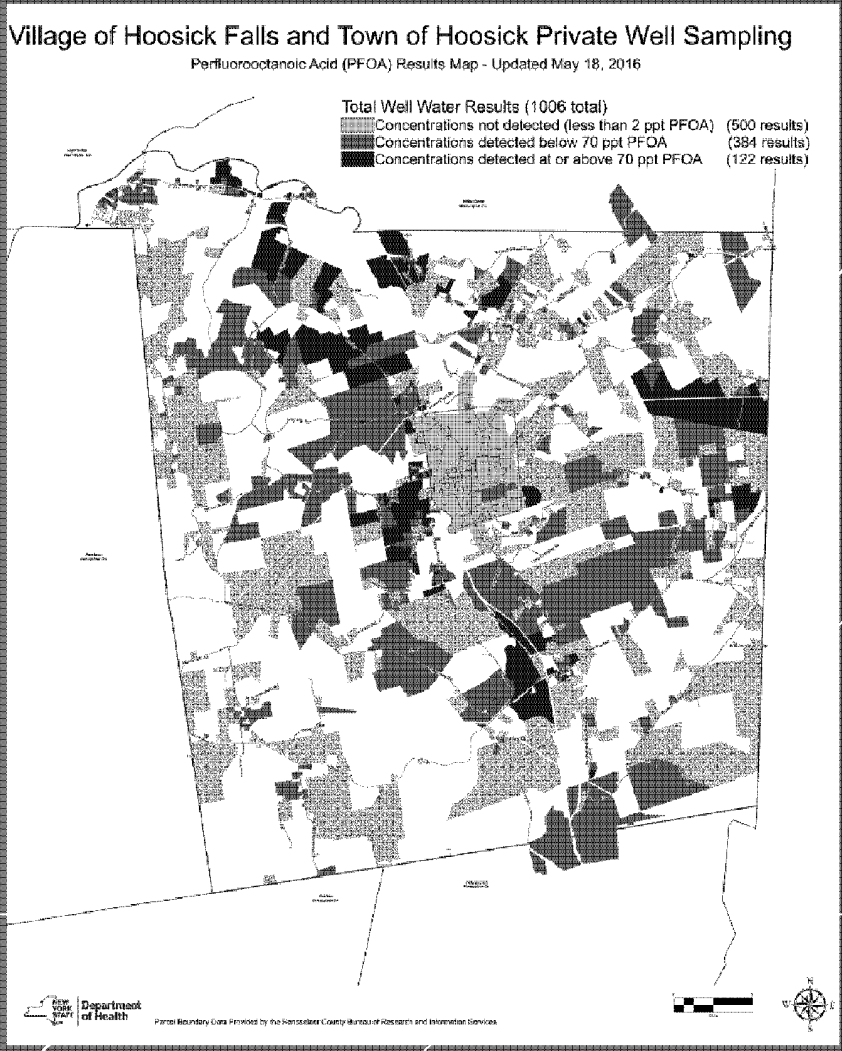
PFOA IN DRINKING WATER

HOOSICK FALLS, NY

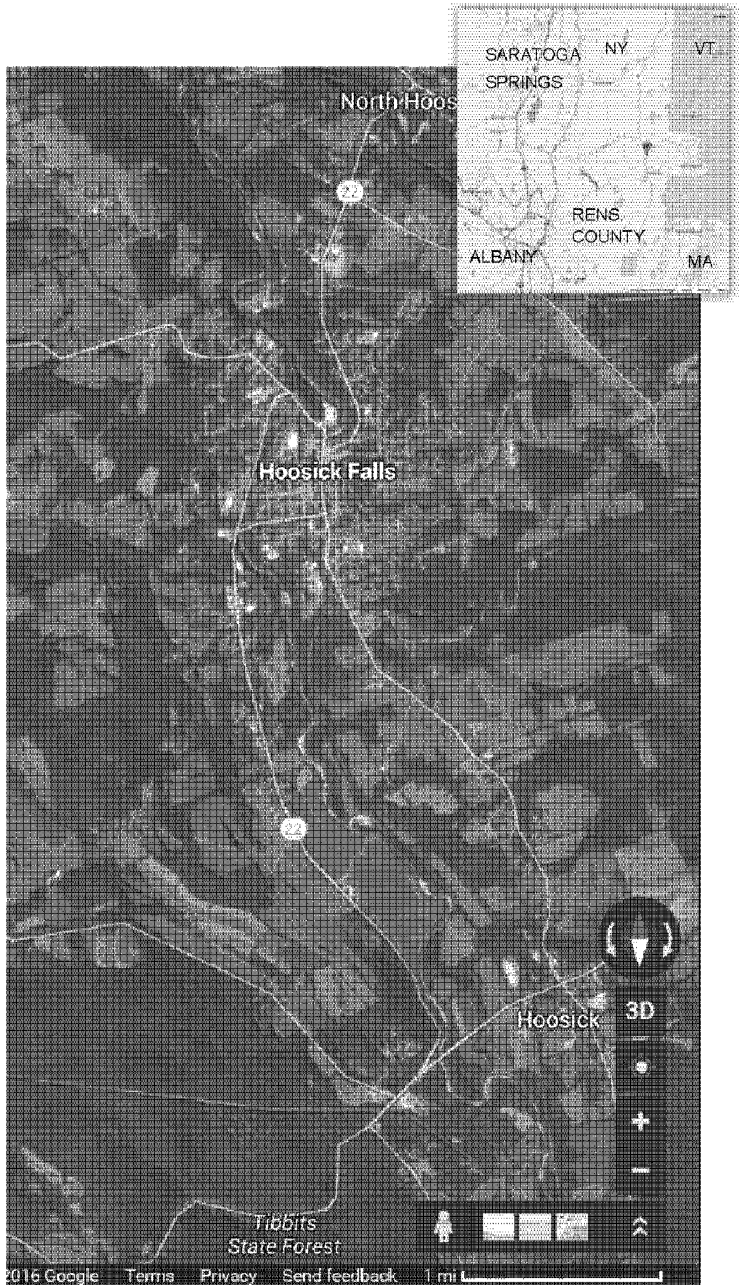
NYS Department of Environmental Conservation



US00022369

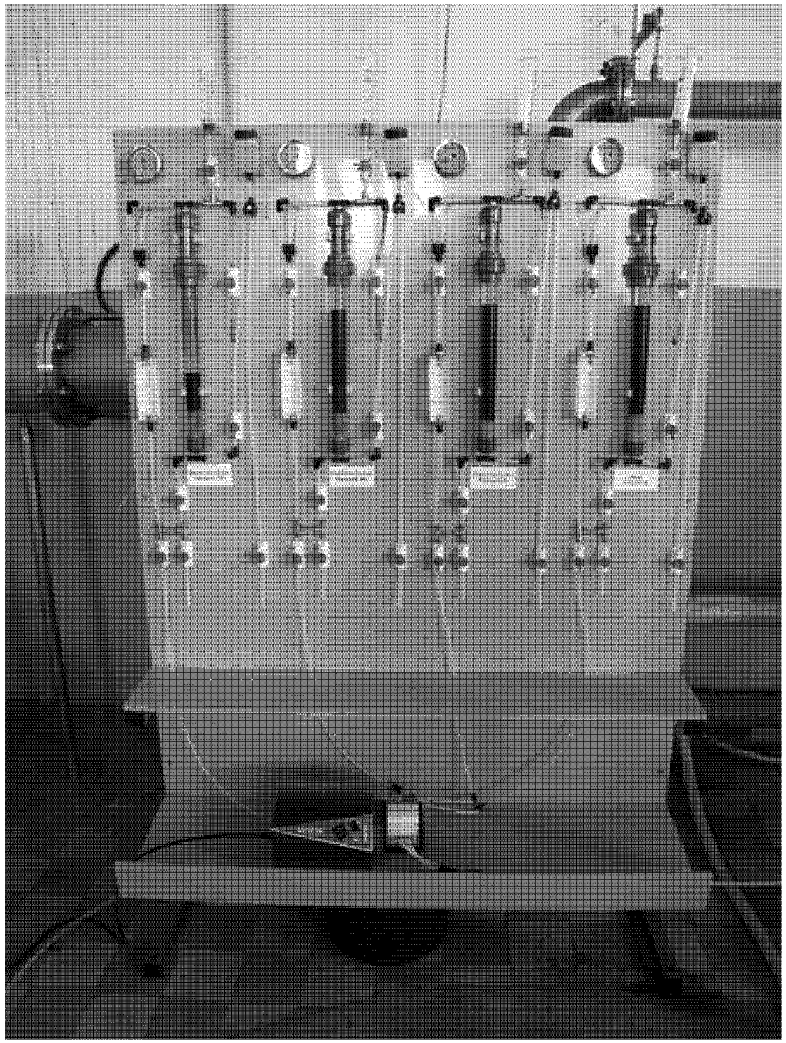
Hoosick Falls, NY

- Community of approximately 3,600 people located in northeastern Rensselaer County, NY– about 10 miles from NY – VT border.
- Situated along the Hoosic River – a 70-mile long tributary to the Hudson River with a 720 square-mile watershed in 3 states – VT, MA, and NY.
- Mix of residential, commercial and industrial zones.
- PFOA detected in Village water supply wells and other private wells.
- New York State responded by listing Saint-Gobain Performance Plastics on the State Superfund List.
- NYSDEC set up an Incident Command Center to respond to needs of residents, business owners and village officials.



Hoosick Falls - NYSDEC Work Assignments

- **Treatment System Design and Construction** – GAC treatment systems on water supply for schools and apartment complex
- **POET System: Bench-scale Testing**
- Small scale treatability testing (e.g. rapid small-scale column testing, RSSCT)
  - correctly design/size the treatment system
  - provides an estimate of expected service life to breakthrough.
  - performed within a much shorter time that a pilot or full-scale test.
- Because of the rapid response needed in this case, POET systems were being installed concurrently with design verification tests using via RSSCTs.



Hoosick Falls - NYSDEC Work Assignments (cont.)

- **Engineering Oversight –** installing Point-of-Entry Treatment (POET) systems on approximately 900 residential and commercial water supply systems.
- **Incident Command Center -** Leading situational and planning tasks, operating call centers, scheduling field tasks, inventorying POET equipment, collecting and recording field and system data.
- **POET System Operation, Maintenance & Monitoring –** 20 months of PFOA water sampling and operations/maintenance of approximately 900 POET systems installed by NYSDEC contractors
- **Alternative Water Supply Development** (2 to 3 MGD: adjacent alluvial Valley): Confined (protected) aquifer identified using geophysics; confirmed with Hydraulic and chemical testing.

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BEST MANAGEMENT PRACTICES

FOAM INVENTORY & PRODUCT SUBSTITUTION

PFAS Manufacturing

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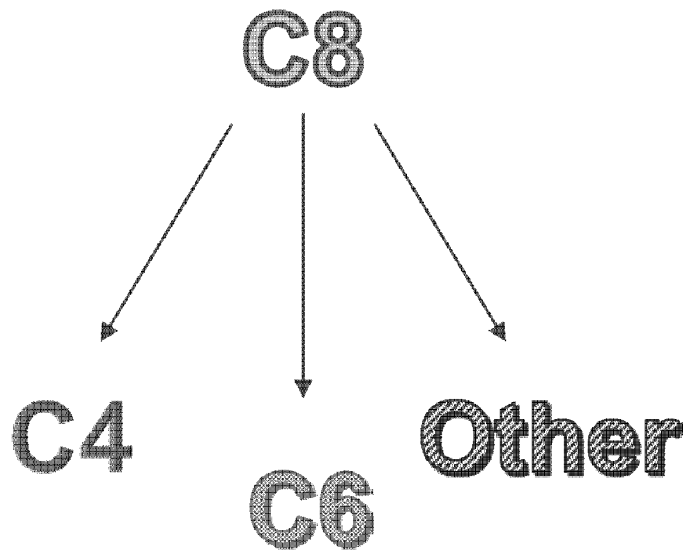
- In most of the U.S. and Europe, C8 PFAS species have been phased-out due to potential health concerns
- PFOS (C8) and PFOA (C8) and related PFAS have been replaced with compounds with shorter (e.g., C4, C6) perfluorinated chains
- Shorter chain replacement chemicals are typically less bioaccumulative, but they are still persistent and more mobile in aqueous systems vs C8.
- Solutions for characterizing all PFAS species, from C4 to C8, are imperative; all carbon chain lengths are present in most environmental samples and even in historical "C8" products



Non-fluorinated replacement foams are being adopted widely

AFFF Usage in U.S.

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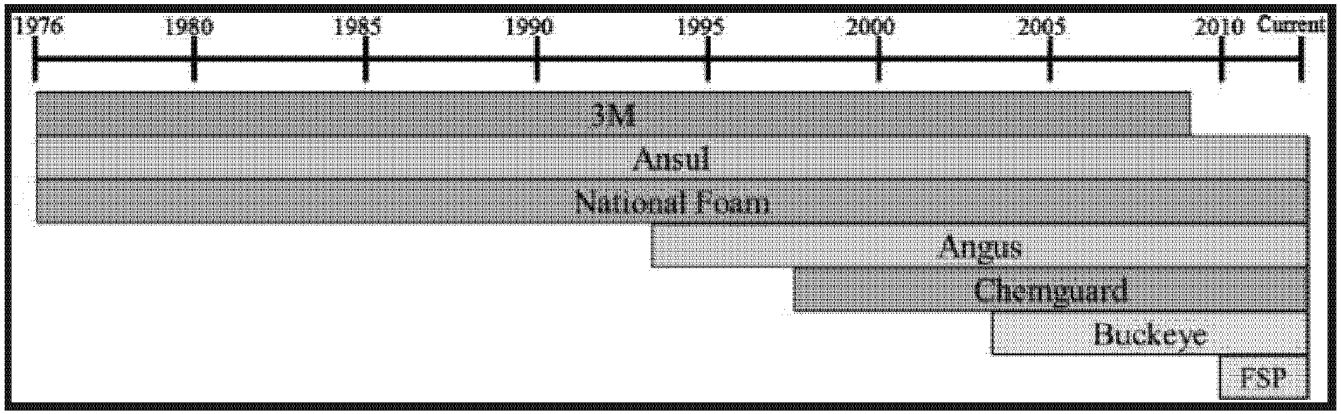
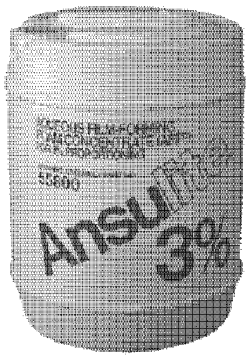
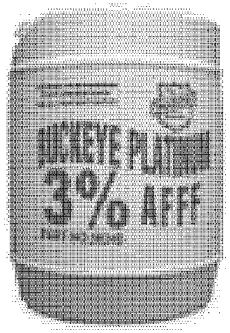


- Navy developed AFFF with 3M after the devastating USS Forrestal Fire in 1967 (134 dead, 161 injured)
- Historically, AFFF contained PFOS, PFOA, and C8 and C6 precursors – exact PFASs used are manufacturer dependent
- Since early 2000's, U.S. military and airports use fluorotelomer-based foams that contain C6 compounds – they do not contain PFOS/PFOA and PFOS/PFOA precursors
    - Common brand names are Ansulite, National Foam Aer-o-Water, Buckeye, Chemguard (all MilSpec approved)





Fluorine Free Foam Replacements to PFAS-AFFF are Available

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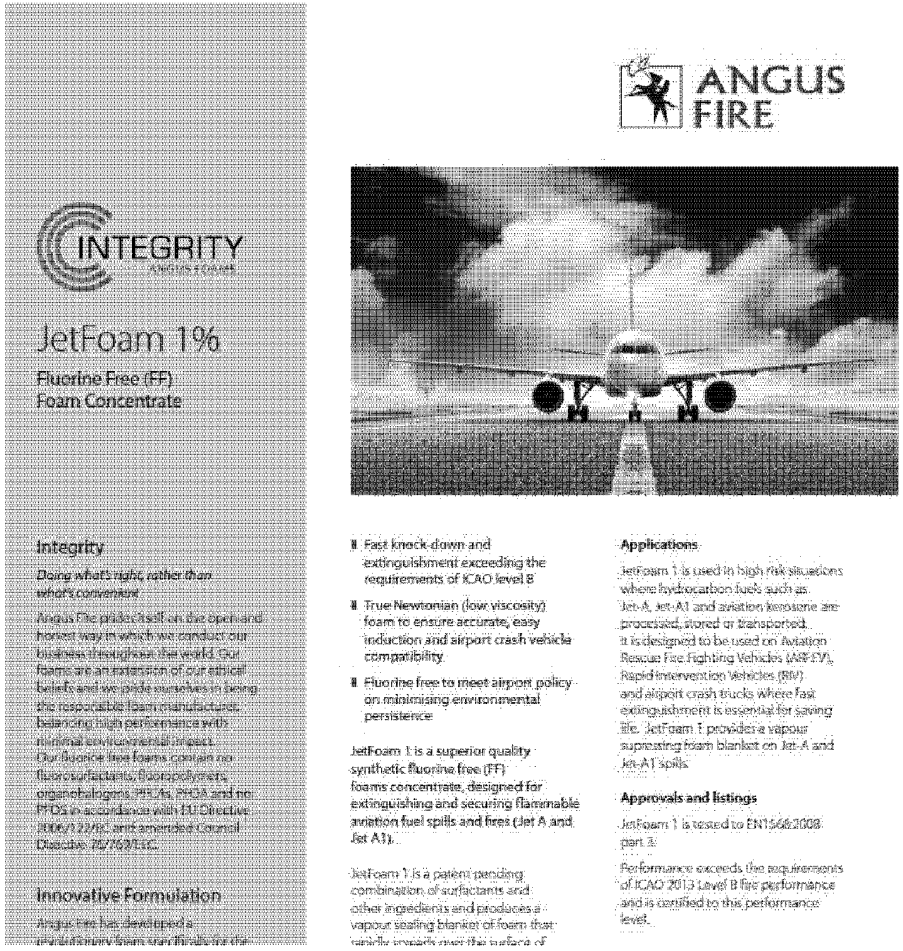
Fluorine Free AFFF

Manufacturer	Foam
Bioex	Ecopol
Fomtec	Enviro 3x3 Plus
Solberg	Re-healing Foam RF6 / RF3
Dr. Sthamer	Moussol F-F3/6



INTEGRITY

JetFoam 1%

Fluorine Free (FF)
Foam Concentrate

Integrity

Doing what's right, rather than what's convenient

Angus Fire prides itself on the open and honest way in which we conduct our business throughout the world. Our foams are an extension of our ethical beliefs and we pride ourselves in being the responsible foam manufacturer, balancing high performance with minimal environmental impact. Our fluorine free foams contain no fluorosurfactants, fluoropolymers, organohalogens, PFOS, PFOA and no PFOs in accordance with EU Directive 2006/122/EC and amended Council Directive 76/769/EEC.

Innovative Formulation

Angus Fire has developed a revolutionary foam and finally for the

ANGUS FIRE

- Fast knock-down and extinguishment exceeding the requirements of ICAO level B
- True Newtonian (low viscosity) foam to ensure accurate, easy induction and airport crash vehicle compatibility
- Fluorine free to meet airport policy on minimising environmental persistence

JetFoam 1 is a superior quality synthetic fluorine free (FF) foams concentrate, designed for extinguishing and securing flammable aviation fuel spills and fires (Jet A and Jet A1).

JetFoam 1 is a patent pending combination of surfactants and other ingredients and produces a vapour sealing blanket of foam that quickly travels over the surface of

Applications

JetFoam 1 is used in high risk situations where hydrocarbon fuels such as Jet-A, Jet-A1 and aviation kerosene are processed, stored or transported. It is designed to be used on Aviation Rescue Fire Fighting Vehicles (ARFFV), Rapid Intervention Vehicles (RIV) and airport crash trucks where fast extinguishment is essential for saving life. JetFoam 1 provides a vapour supressing foam blanket on Jet-A and Jet-A1 spills.

Approvals and listings

JetFoam 1 is tested to EN1568:2008 part 3.

Performance exceeds the requirements of ICAO 2013 Level B fire performance and is certified to this performance level.

Solberg foams are used by many airports in Europe

Fluorine free foams work via mechanisms that involve aspiration (nozzles that introduce bubbles)

Alternative fluorine free foams may have higher COD/BOD

MILSPEC requires 30s extinguish time, and fluorine free foams currently do not meet this criteria

In Summary

- Overview of the PFAS issue to provide the knowledge needed to avoid impulsive reactions
- Understand how PFAS reacts in the environment to ensure the most appropriate sampling and analytical methods and treatment technologies are selected
- Have the information needed to allow you to focus on your mission and direct your program going forward.

We are READY to Help

SERDP & ESTCP
Research Efforts on PFCs

Andrea Leeson, Ph.D.
Environmental Restoration Program Manager

Overview

- SERDP Efforts
  - FY11 projects focused on fate and transport
  - FY14 projects focused on development of remedial technologies
  - FY16 projects focused on ecotoxicity
- ESTCP efforts
  - Further characterization of the total footprint of PFAS contamination at field sites at Navy and other DoD sites.
  - Transfer of a base of knowledge of both the types of PFASs that occur at military sites as well as how they can be reliably measured in environmental media to the target audiences.

ER-2128
Characterization of the Fate and Biotransformation of Fluorochemicals in AFFF-Contaminated Groundwater at Fire/Crash Testing Military Sites

Performers

- *Drs. Jennifer A. Field, Markus Kleber, David L. Sedlak, and Lisa Alvarez-Cohen*

Technology Focus

- *Occurrence and fate of per- and polyfluoroalkyl substances (PFAS) at US military sites contaminated by aqueous film-forming foams (AFFF)*

Research Objectives

- *Complete characterization of PFAS occurrence in soil, sediment, and groundwater. Biotransformation of PFAS and their impact on TCE (priority pollutant) reductive dechlorination.*

Project Progress and Results

- *Identification of PFAS in AFFF. Characterization of PFAS in groundwater/sediment/soil and the presence of unknown PFAS. Identification of biodegradation pathways/products.*

Technology Transition

- *Translation of analytical methodologies to private sector laboratories; support development/implementation of remediation technologies for PFAS*

FY14 Selected Projects: In Situ Remediation of Perfluoroalkyl Contaminated Groundwater

	ER-2423 Clarkson University	ER-2424 Shaw Environmental	ER-2425 University of Minnesota	ER-2426 Purdue University
Technology	GAC sorption combined with destruction using activated persulfate oxidation	Electrocatalytic and catalytic approaches	Chemical coagulants	Coupled reductive & oxidative processes
Objective	Evaluate feasibility, effectiveness, & sustainability of treatment train approach where activated carbon is used to sorb & concentrate contaminants, followed by contaminant destruction & carbon regeneration in situ using activated persulfate	Develop & assess use of electrocatalytic & catalytic approaches for in situ treatment of PFASs in groundwater	Develop cost-effective, in situ method using coagulants to sequester six PFAS in groundwater systems	Test effectiveness of reductive technologies & couple most successful to oxidative technologies to obtain highly effective destruction in a cost effective in situ treatment train

ER-2423: In Situ Treatment Train for Remediation of Perfluoroalkyl Contaminated Groundwater: In Situ Chemical Oxidation of Sorbed Contaminants (ISCO-SC)

Performers: Clarkson University, ARCADIS, SNWA

Technology Focus

- *A combined remedy for remediating perfluoroalkyl contaminated groundwater: sorption onto granular activated carbon (GAC) and destruction using activated persulfate oxidation.*

Project Objective

- *Evaluate the feasibility, effectiveness, and sustainability of a treatment train approach: In Situ Chemical Oxidation of Sorbed Contaminants (ISCO-SC)*

Project Progress and Results

- *Sorption of perfluoralkyl contaminants onto GAC depends on carbon type, PFC chain length, initial PFC concentration, presence in mixture, carbon pre-treatment processes. PFOA can be oxidized through shorter-chain compounds by heat-activated persulfate; however, PFOS is resistant to oxidation under most conditions tested. The HRX well focuses flow predictably, and equations to model flow focusing have been validated.*

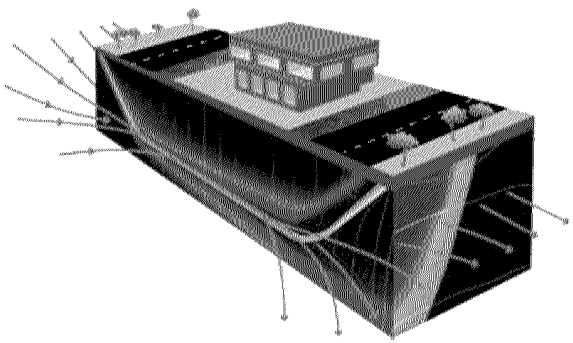
Implementation Outlook

- *Data to date support feasibility of sorbing SOME perfluoroalkyl contaminants onto activated carbon and their destruction by heat-activated persulfate oxidation.*

Clarkson UNIVERSITY defy convention

Southern Nevada Water Authority

ARCADIS



ER-2424: Investigating Electrocatalytic and Catalytic Approaches for In Situ Treatment of Perfluoroalkyl Contaminants in Groundwater

Performers: C. Schaefer (CDM Smith), C. Andaya (CB&I), C. Higgins & T. Strathmann (Colorado School of Mines), L. Ferguson (Duke University), A. Urtiaga (University of Cantabria)

Technology Focus

- *Electrochemical and catalytic treatment of PFASs*

Research Objectives

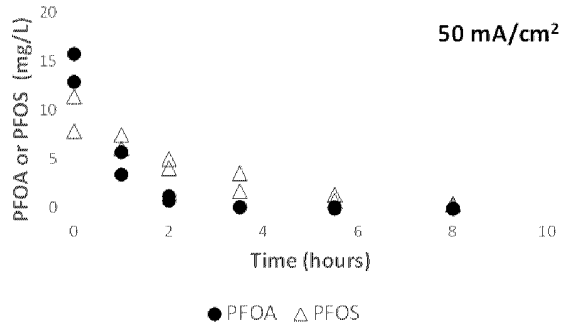
- *Sustained defluorination of the wide range of PFASs present in groundwater at AFFF-impacted sites*

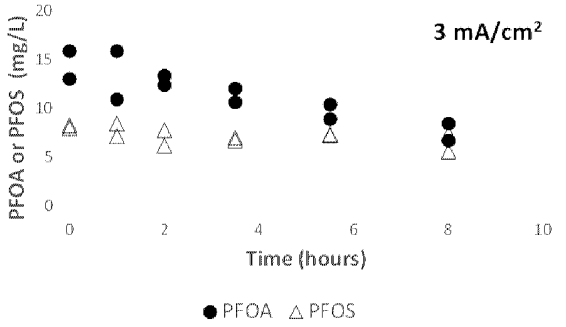
Project Progress and Results

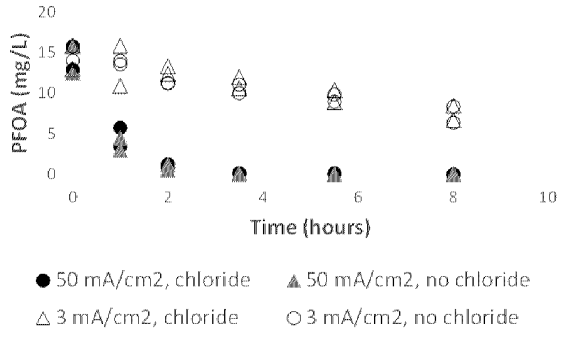
- *BDD diamond anodes are effective for defluorination of PFOA and PFOS, and performance is not impacted by the presence of chloride*
- *Rh-based hydrogenation catalysts and B12 catalysts are not effective for defluorination of linear perfluorinated compounds*
- *Hydrated electrons show promise for defluorination of PFOS & PFOA*

Technology Transition

- *Peer reviewed papers, conference presentations, and presentations to USEPA regions 1 and 2*







ER-2425: Development for a Novel Approach to in situ Remediation of PFC Contaminated Groundwater

Performers: Matt Simcik, Bill Arnold – UMN; Kurt Pennell – Tufts;James Hatton, Bill Diguiseppi – CH2MHill

Technology Focus

- *Increased sorption of PFAS by employing drinking water coagulants as sorption enhancers*

Research Objectives

- *Reduce dissolved phase concentration of the six PFAS on the UCMR3 list below a health based limit of 0.3 ug/L*

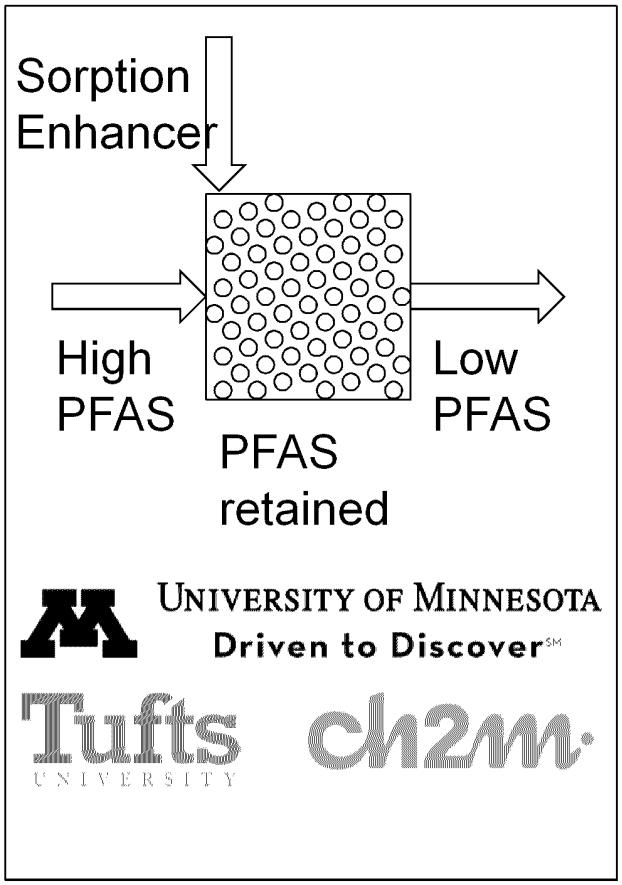
Project Progress and Results

- *To date we have identified two sorption enhancers capable of reaching our goals, and calculate effective dosages*

Technology Transition

- *Field implementation – DOD Fire Training Activity Areas*
- *Transfer technology to activated carbon drinking water treatment currently in use at DOD facilities*

NOTE: This slide may used by the Program Office in future presentations to provide a brief overview of the project.



Ecotoxicity of Perfluorinated Compounds

	ER-2624 University of Minnesota	ER-2625 US Army PHC	ER-2626 Purdue University	ER-2627 Towson University
Target Animals	Avian	Mammalian	Amphibians	Invertebrates, fish, avian, and reptiles
Objective	Develop avian ecotoxicity information for compounds associated with aqueous film forming foam (AFFF) in birds.	Fill primary toxicological data gaps for PFOA and PFOS with bioassays that use representative laboratory animal models.	Develop amphibian TRVs for PFASs common to AFFF impacted sites for a suite of species exposed at different life stages, lengths, and routes using established ecotoxicity testing approaches.	Conduct ecotoxicty studies that yield TRVs for wildlife potentially exposed to common PFAS and to develop a low-cost, relative toxicity protocol for evaluating other PFAS that may drive risks at DoD sites.

Characterization of the Nature & Extent of PFASs in Environmental Media at DoD Sites for Informed Decision-Making (ESTCP)

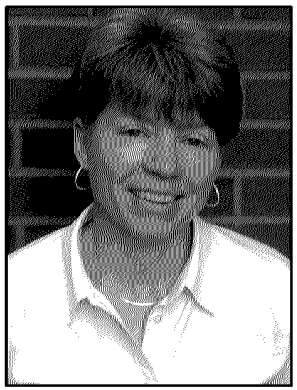
- ***Goal:*** To characterize the total footprint of PFAS contamination at field sites to enable fingerprinting of AFFF-based sources as compared to non-AFFF sources as well as to determine the nature and extent of PFAS source areas at Navy and other DoD sites.
- ***Progress:*** Only recently initiated work in 2016. This project will provide results of recent efforts to the ER Technical Committee in July 2016.
- ***Final Products:*** Final report due in 2018. The team also plans tech transfer efforts through micro-lectures and a one- to two-page summary of results.
- ***Lead Investigator:*** John Kornuc (NAVFAC EXWC)
- ***Web Site:*** https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-201633/ER-201633

Catalyzing Rapid Information Transfer among Key Stakeholder on Per- and Polyfluoroalkyl Substances (PFASs) at contaminated Military Sites (ESTCP)

- **Goal:** To expedite the transfer of a base of knowledge of both the types of PFASs that occur at military sites as well as how they can be reliably measured in environmental media to the target audiences.
- **Progress:** On site analytical workshops have been held and will be complete within the next few months. The remaining tech transfer products will be completed by May 2017.
- **Final Products:** An extended Reference Document and a succinct Frequently Asked Questions (FAQ) sheet, videos, on-line workshops for RPMs, and on-site “hands-on” workshops for vendor (commercial) laboratories.
- **Lead Investigator:** Jennifer Field (Oregon State University)
- **Web Site:** https://serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-201574-T2

State of Knowledge on Per- and Polyfluoroalkyl Substances (PFASs) at Military Sites

Jennifer Field, Ph.D.
Oregon State University



Project Team

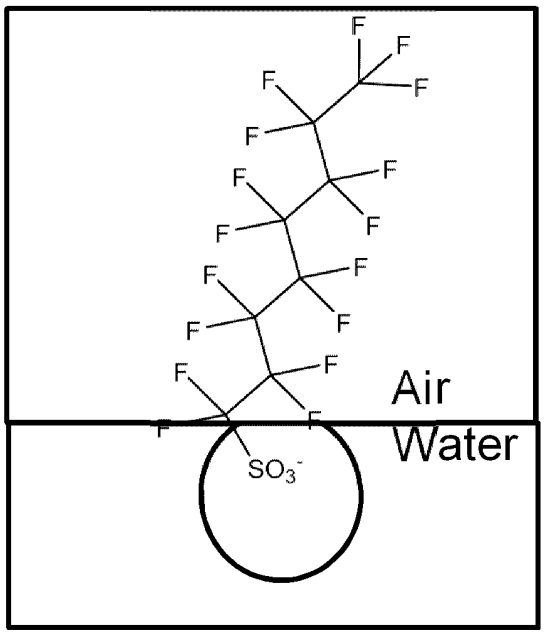
- Dr. Jennifer A. Field, Oregon State University
  - ♦ Environmental analytical chemist
- Dr. David L. Sedlak, UC Berkeley
  - ♦ Advanced oxidation and contaminant fate expert
- Dr. Lisa Alvarez-Cohen UC Berkeley
  - ♦ Environmental microbiologist/engineer
- Dr. Markus Kleber, Oregon State University
  - ♦ Soil scientist

Technical Objectives

- Characterize per- and polyfluoroalkyl substances (PFAS) composition of aqueous film-forming foam (AFFF) formulations
- Characterize PFAS and precursor composition of AFFF-contaminated groundwater, sediment and soil
- Characterize PFAS biodegradation under aerobic and anaerobic conditions
- Characterize the sorption of the newly-identified anionic, cationic and zwitterionic PFASs

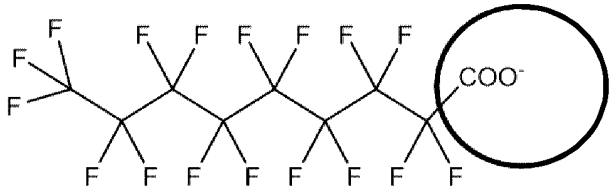
Unique Chemistry of PFASs

- C-F bond is the shortest & strongest in nature
  - ✓ hydrophobic & oleophobic[1]
  - ✓ less predictable behavior in laboratory & environmental systems



PFOS (***per***fluorooctane sulfonate)

- Few engineered/environmental degradation processes, stable in:
  - ✓ heat
  - ✓ acid/base
  - ✓ oxidants
  - ✓ biological systems

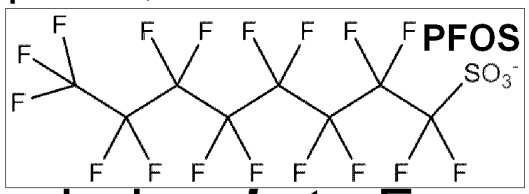


PFOA (***per***fluorooctanoate)[14]

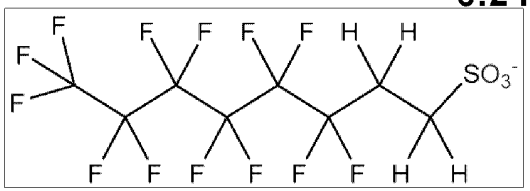
[1]Krafft and Riess 2015 Chemosphere 129:4-19

PFASs vs. ~~PFCs~~

- **PFAs = Per and polyfluoroalkyl substances**
- **Communicate accurately**
  - ✓ contract laboratories, regulatory community, the public, internationally[1]
- **PFC = 'Perfluorinated' = restrictive term**
  - ✓ all carbons in aliphatic chain must be bonded ***only*** to F
  - ✓ no degradation in environment
- **Polyfluorinated = <u>not a</u>ll carbons in chain bonded to F**
  - ✓ CH_2 – linkages create 'weakness' in molecule
  - ✓ susceptible to biodegradation, abiotic processes (oxidation)



6:2 FTSA



[1]Buck et al. 2011 Integr Environ Assess Manag 7:513-541

Why are PFASs Emerging Now

- Traditional analytical instruments (GC/MS) for priority pollutants are 'blind' to non-volatile PFASs
- PFAS are measured by LC-MS/MS
  - ✓ Commercial LC-MS/MS < 15 yrs ago
  - ✓ Quality standards <10 yrs
  - ✓ Standards for telomer sulfonates = 2015!
- Significance of field reports of *foaming groundwater and soil* overlooked

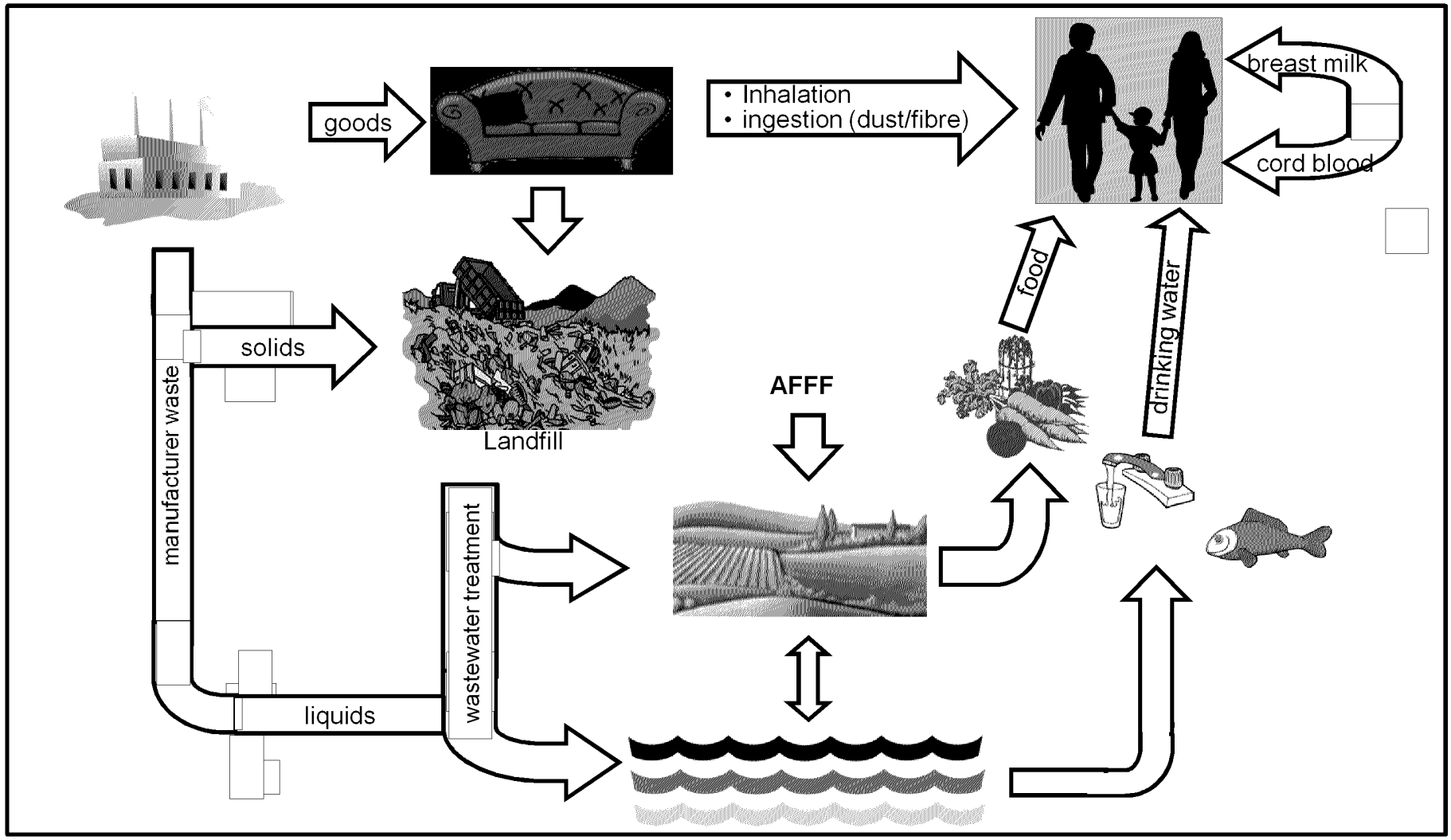
Speculation: we associate foam with fun, not contamination

PFOA & PFOS Toxicity

- **Carcinogenicity**
  - Production workers[1-3] and exposed community studies – 70,000 Ohio & West Virginia residents (C8 Health Project)[4]
- **Immunotoxicity**
  - Negative associations with antibody levels in children[5] and adults[6]
- **Many PFASs detected in human blood**
  - US, China, Germany (PFSAs, PFCAs, amides, acetic acids, telomer sulfonates, phosphinates, phosphates)[1]
- **Based on 3M (industrially-exposed) workers**
  - PFOA 2.3 yrs[2] -3.8 yrs[3] ; PFOS 4.8-5.4 yrs[3]
  - PFHxS 7.3–8.5 yrs[3] (longest reported half life of PFASs)
  - PFBS 25.8 days[4]

[1]O'Berg et al. 1987 J Occup Med; [2] Deposition: Hearing before Leach et l vs. EI DuPont de Nemours Company. Civil Action No 01-C-608, Circuit Court of Wood County, West VA, June 25, 2004; [3]Alexander et al. 2003 Occup Environ Med; Lundin et al. 2009 Epidemiology; [4]Steenland and Woskie, 2012, Am J Epidemiol; [5]Grandjean et al 2012, JAMA; [6]Granum et al. 2013 J Immunotox; [7]Yeung et al. 2016 Env Chem; [8]Bartell et al. 2010, Environ Health Perspec;[9]Olsen et al. 2007 Environ Health Perspect;[10]Olsen et al. 2009, Toxicol

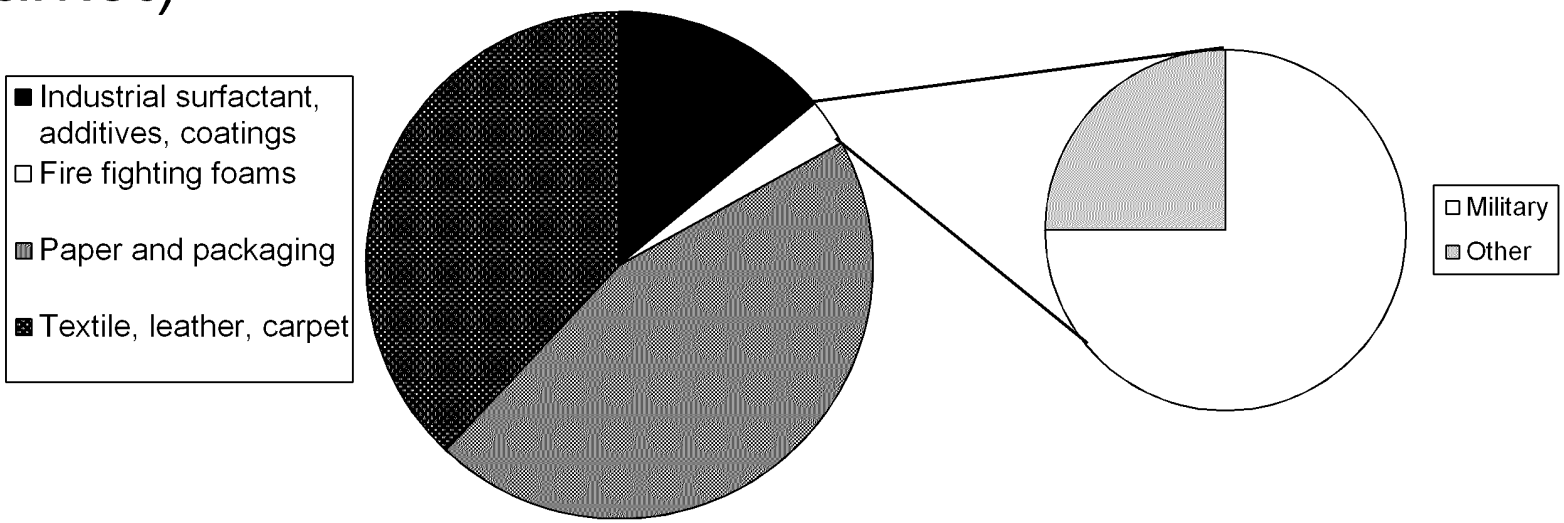
Sources & Exposure Pathways



Adapted from Oliaei 2013 Environ Pollut Res 20:1977-1992

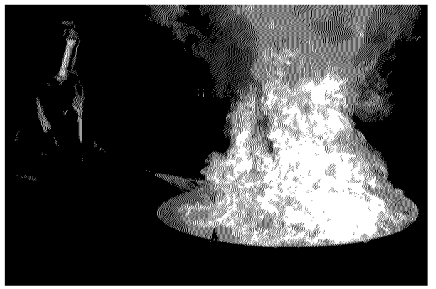
Total 3M PFAS Production and AFFF

- Only 3% of 3M's C8-based PFASs used in AFFF[1]
- Military uses 'lions share' of AFFF (75% of AFFF market)[2]



[1]US EPA 2000; [2]Moody et al. 2000 ES&T 34:3864-3870

AFFF History



- **Proprietary mixtures**
  - ✓ Complex mixtures with ***g/L*** PFASs
- AFFFs (MilSpec) on Qualified Product List[1]
  - ✓ 1965-1976 Light Water (3M)
  - ✓ 1976 Ansulite (Ansul) and Aer-O-Water (National Foam)
  - ✓ 1994 Tridol (Angus)
  - ✓ After 2002 Chemguard (Chemguard), Buckeye (Buckeye), Fireaide (Fire Service Plus)
- **Bottom line**: Multiple AFFFs used at most sites
- **Detection frequencies**:[2] testing/maintenance > hangars/buildings > emergency response
- **Other:** pipes, storage container areas, oil-water separators, waste disposal sites

[1]Steve Fletcher, Fire Protection Engineer, NAVSEA HQ, SEA 05P5; [2]Anderson et al. 2016 Chemosphere;Photo courtesy of John Farley, Director, CBD/ex-USS SHADWELL Fire Test Operations, Naval Research Laboratory, Washington DC

AFFF: Equipment Testing & Training[1]

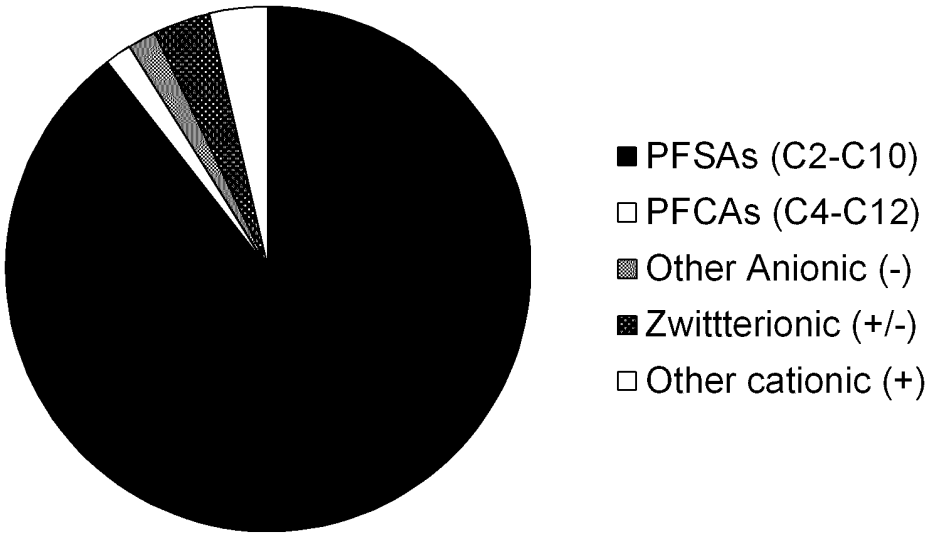
Test type	Diluted AFFF (gal)	AFFF (L)	Event/ yr	PFOS (kg)	PFOA (kg)	ΣPFAS (kg)	Σ20 yr (kg)
Capacity[2]	3,000	341	1	**3.2**	0.032	4.7	**93**
Nozzle discharge[2]	10	1.1	1	0.01	0.0011	0.015	**0.31**
Training[3]	20	2.3	4	0.084	0.0084	0.12	**2.5**
Crash[4]	50,000	5,678		**53**	5.3	**77**	

- Annual equipment testing NFPA 412 stopped by Air Force in 2015
- Most personnel training with 'live' AFFFs (all formulas) stopped 1990s-2000s

[1]Kevin Matlock, Fire Emergency Services, AFCEC/CXF;[2]No fuel used, testing specified in National Fire Association (NFA) Standard 412, annual testing suspended by Air Force in 2015;[3]500-700 gallons fuel used & training varied by base, twice per year required, may have been quarterly depending on personnel training schedule

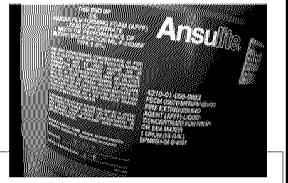
3M AFFF: Sole Source 1965-1975

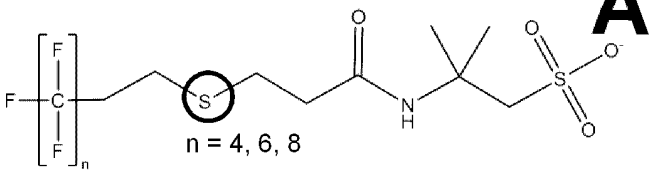
- 89% PFSAs (e.g., PFOS) in 3M AFFF[1-3]
- *Only* 1.6% PFCAs(e.g., PFOA)
- *All* contribute to total fluorine

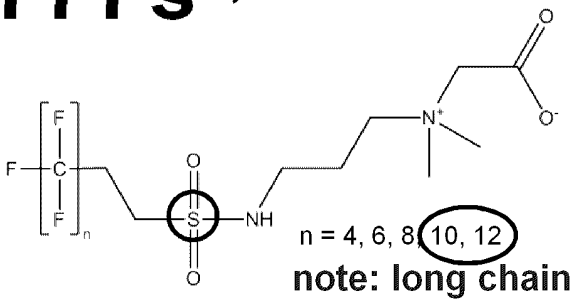


[1]Place et al. 2012, ES&T 46:7120-7127;[2]Backe et al. 2012 ES&T 47:5226-523;[3]Barzen-Hansen and Field 2015 ES&T Letters 2: 95-99

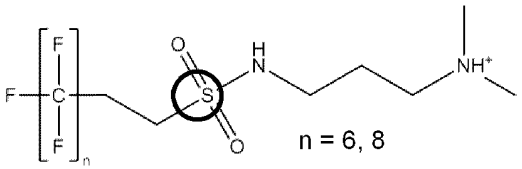
Polyfluorinated forms in Fluorotelomer AFFFs[1,2]



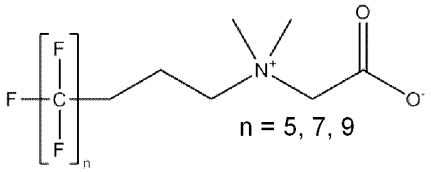


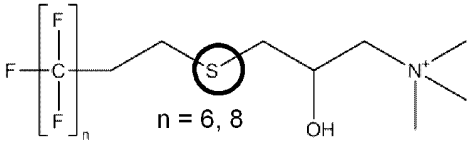


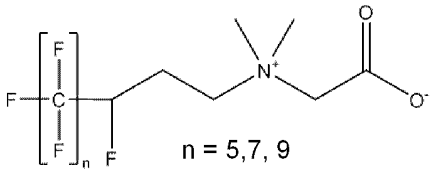
note: long chain lengths!

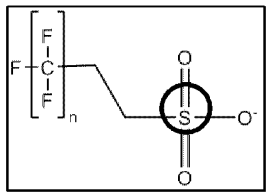


- none listed on UMCR3 & Method 537 lists
- *all* contribute to total F
- –S- forms degrade to FTSAs & short-chain PFCAs[3,4]
- 6:2 & 8:2 FTSAs = major degradation products in groundwater[2] (only trace levels in AFFF)







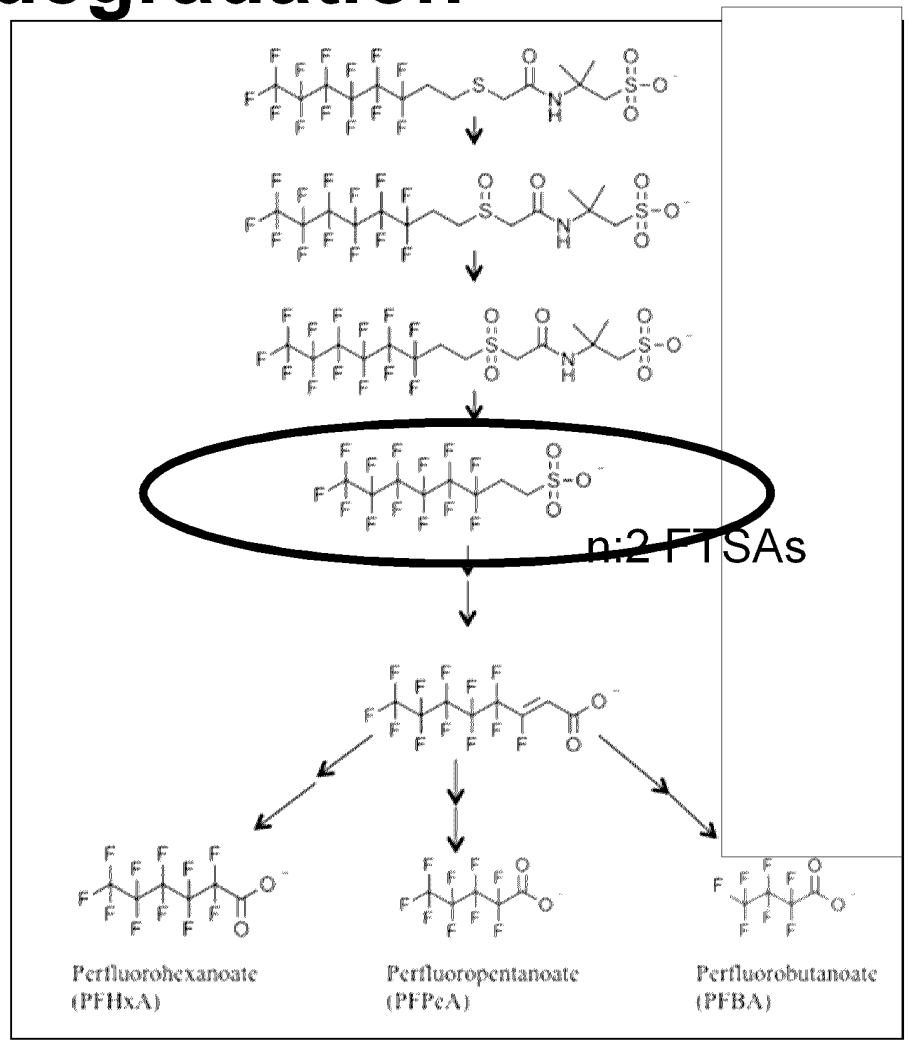


n:2 FTSAs
(biodegradation intermediate)

[1]Place et al. 2012, ES&T 46:7120-7127;[2]Backe et al. 2012 ES&T 47:5226-5234;[3]Weiner et al. 2013 Environ Chem 10:486-493; [4]Harding-Marjanovic et al. 2015 ES&T 49:7666-7674

Aerobic Biodegradation

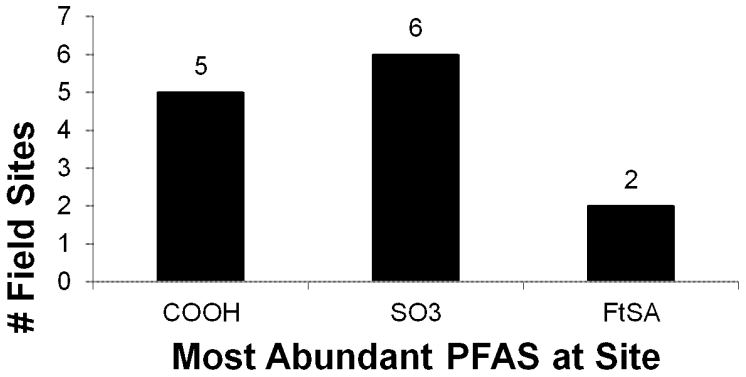
- Ansul precursor degrades to FTSAs & short-chain (≤ C6) PFCAs[1,2]
- FTSAs >> precursors in site groundwater[3]
- FTSAs stable under anoxic conditions ~ decade
- -SO- and -SO_2- intermediates in groundwater

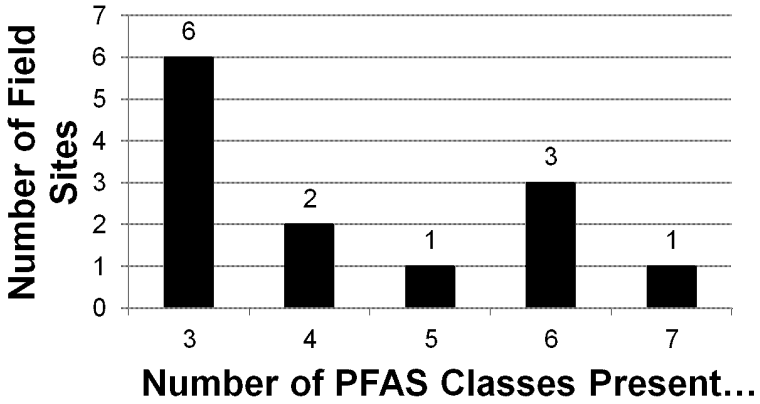


[1]Weiner et al. 2013 Environ Chem 10:486-493; [2]Harding-Marjanovic et al. 2015 ES&T 49:7666-7674;[3]Backe et al. 2012 ES&T 47:5226-5234

PFASs in Groundwater at Military Bases

- 13 Air Force & Navy bases
- PFSAs and PFCAs not always the most abundant
- PFSAs & PFCAs concentrations >> EPA's HAs
- No site has just PFSAs & PFCAs
- Groundwater concentrations greater than any other aqueous media[1]
  - ✓ PFOS = 1 mg/L
  - ✓ PFOA = 6.6mg/L
  - ✓ 6:2FTSA = 14 mg/L





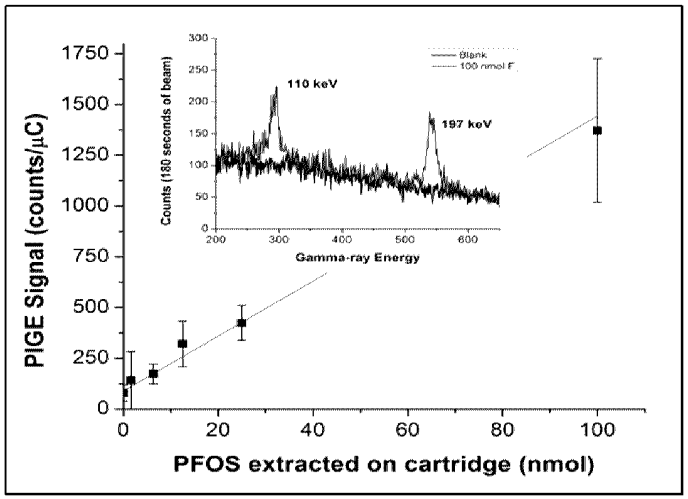
[1]Schultz et al. 2004 ES&T 38:1828-1835

Closing the Mass Balance: Why Care?

- Many PFASs used in AFFF & identified in groundwater, sediment/soil that won't be 'lists' any time soon
- Selection of remedial treatments and treatment of drinking water sources requires knowledge of 'targets'
- Increasing regulator and public awareness regarding presence of precursors and 'other' PFASs
- **Bottom line:** Minimizing/preventing future liabilities

Towards Mass Balance on Fluorine

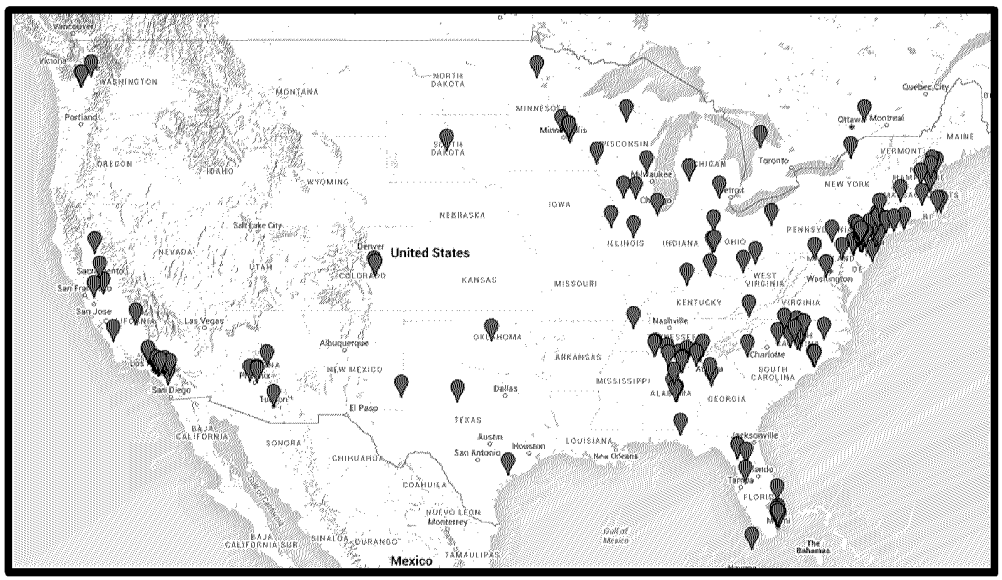
- Additional analytical tools for closing the mass balance on fluorine:
- Total oxidizable precursor (TOP) assay
  - ✓ Quantifies precursor (total PFASs) in groundwater, sediment, soil[1]
  - ✓ Closes mass balance in microcosm studies[2]
- Total fluorine by PIGE[3]
  - ✓ PFAS in groundwater sorbed onto media to create 'target'
  - ✓ 10 nA of 3.4 MeV protons for 180 s
  - ✓ Quantitative, high-throughput
  - ✓ Inexpensive screening tool



[1]Houtz et al. 2013 ES&T 47:9342-9349;[2]Harding-Marjanovic et al. 2015 ES&T 49:7666-7674;[3]Lunderberg et al. 2015 Fluoros, Golden, CO;

UCMR3 Data: Public Water Supply

- UCMR3: public water systems serving > 10,000 people
- 3 PFSAs & 3 PFCAs analyzed
- Positive hits (>MRL) for one or more PFASs (June 2015 database)
- Drinking water important source of short-chain PFASs[1-3]



[1]Gyllenhammar et al. 2015 Environ Res 140:673-683;[2]Eschauzier et al. 2013 Sci Tot Environ 458:477-485;[3]Weiss et al. 2012 Intl Hyg Environ Health 215:212-215

Sources & Fingerprinting

- **Landfill Leachate (municipal refuse/consumer products)**
  - ✓ 2nd place (μg/L)[1-3]
  - ✓ short-chain PFCAs & fluorotelomer acids[3]
- **Municipal wastewater effluent**
  - ✓ 3rd place (< 0.1 μg/L)[4-6]
- **Chromium electroplating (mist suppression)**[7,8]
- **Industrial (plastics/polymer) manufacturing**
  - ✓ PFNA in NJ[9] & PFOA in NY[10]
- **Other:** municipal airports & fire departments, oil refineries

[1]Allred et al. 2014 J Chrom A 1359: 202-211;[2]Allred et al. 2015 ES&T 49:7648–7656;[3]Benskins et al. 2012 ES&T 46:11532-11540; [4]Schultz et al. 2006 ES&T 40:289-295l;[5]Sinclair and Kannan 2006 ES&T 40:1408-1414 ;[6]Logananthan et al 2007 Water Res 41:4611-4620;[7]EPA Region 5 PFOS Chromium Electroplater Study, 2009; [8]Yang et al. 2014 Env Sci Pollut 21:4634-4642Res;[9]http://www.njspotlight.com/stories/15/04/06/drinking-water-panel-calls-for-stricter-standard-on-potential-carcinogen/;[10]http://www.villageofhoosickfalls.com/news.html

Transport Generalizations

- Transport related to chemical structure & charge/ionization
  - ✓ For anions, shorter chain lengths generally migrate faster (less retardation, lower Koc)[1-3]
    - likely to impact surface waters
    - challenging to remove by GAC[4]
  - ✓ Transport potential: anions > zwitterions > cations
  - ✓ For many polyfluorinated forms, transport will depend on pH and molecule's charged state (ionic or neutral), ionic strength, ion exchange capacity
- Cationic forms potentially cation exchanged onto source-zone sediments
  - ✓ Mobile or immobile under what conditions?
  - ✓ Caution when applying oxidants to source-zone sediments, potential to liberate PFASs as water soluble, short-chain forms[5-9] that are most difficult to remove

[1]Higgins et al. 2006 ES&T,40:7251-7256;[2]Higgins and Luthy, 2007 ES&T 41:3254-3261;[3]Guelfo and Higgins 2013 ES&T 47:4164-4171;[4]Appleman et al. 2014 Wat Res 51:246-255;[5]Houtz and Sedlak, 2012 ES&T 46: 9342-9349;[6]Houtz and Sedlak, 2013 ES&T 47: 8187-8195;[7]Yang et al. 2014, Environ Sci Pollut 21: 4634-4642;[8]Fang et al. 2015 Environ Tox Chem 34: 2625-2628;[9]Park et al. 2016 Chemosphere 145: 376-383

New SERDP/ESTCP Projects

- ESTCP Project ER-201574-T2
  "Catalyzing Rapid Information Transfer Among Key Stakeholders on Per- and Polyfluoroalkyl Substances (PFASs) at Contaminated Military Sites" OSU lead (J. Field)
- SERDP Project ER-2627
  "Advancing the Understanding of the Ecological Risk of Per- and Polyfluoroalkyl Substances" Townson University lead (C. Salice)
- ESTCP Project ER-201633
  "Characterization of the Nature and Extent of Per- and Polyfluoroalkyl Substance (PFASs) in Environmental Media at DoD Sites for Informed Decision-Making" Navy lead (J. Kornuc)

Conclusions

- PFOS and PFOA are important but not the only major PFASs at AFFF-contaminated sites
- Fluorotelomer-based substances partially biodegrade to metastable intermediates, including short-chain PFCAs, but not to PFOS
- Mobility in groundwater anions > zwitterions > cations
- Anion mobility depends on chain length
- Mobility of many substances influenced by sediment, soil and water geochemistry

Benefits of Future SERDP/ESTCP Projects to DoD

- Hundreds of fire/crash testing (mixed waste) sites
- Full characterization of PFAS contamination
  - ✓ More accurate conceptual site models
  - ✓ Identify remedial approaches that decrease time and cost
  - ✓ Optimized monitoring
  - ✓ Fingerprinting to differentiate AFFF from other sources
  - ✓ Source zone identification
  - ✓ Accurate predictions of transport
  - ✓ Indicators of in situ biotransformation
- Groundwater contaminated by PFAS used as drinking water source is a potential exposure pathway for humans and wildlife
  - ✓ Attention to short-chain PFAS highly mobile, difficult to remove from water

For additional information, please visit https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2128

Speaker Contact Information

[redacted]

From: Ohannessian, Karnig H SES OASN EI&E
To: Mach, Richard CIV OASN (EI&E), ODASN (Environment)
Sent: 5/24/2017 8:41:27 PM
Subject: FW: PFAS (incl PFOS & PFOA) LEARNING
Attachments: Chief Read-Ahead PFAS 170519.ppt

For tomorrow, not tonight!

-----Original Message-----
From: Iselin, Steven R SES OASN (EI&E), Principal Deputy ASN EI&E
Sent: Wednesday, May 24, 2017 9:38 AM
To: Ohannessian, Karnig H SES OASN EI&E
Cc: Jensen, Craig D CIV OASN (EI&E), AGC EI&E; Gray, Christopher CAPT OASN (EI&E)
Subject: FW: PFAS (incl PFOS & PFOA) LEARNING

Karnig,

I don't need it today, but could you please provide some advice as to the way ahead with these challenges? Bret's email and this brief open the aperture on this challenge to more than just cleanup...sounds like we have a haz materials challenge (what do to with existing AFFF product) too. The RDTE aspect is interesting...what are others doing outside of Navy to try to solve the technical cleanup challenges? I worry that efforts are moving slowing to ID the replacement AFFF product. Finally, what are the resource implications? Do we need to press for $$$ to help accelerate any of this work?

R

Steve

-----Original Message-----
From: Muilenburg, Bret J RADM NAVFAC HQ, 00
Sent: Tuesday, May 23, 2017 3:53 PM
To: Iselin, Steven R SES OASN (EI&E), Principal Deputy ASN EI&E; Grosklags, Paul A VADM AIR 00; Smith, Dixon R OPNAV, N4; Dana, Michael G MajGen I&L; Jackson, Mary M VADM CNIC HQ, N00; Broadmeadow, John J MajGen I&L, MCICOM; Ohannessian, Karnig H SES OASN EI&E; Balocki, James SES, OASN (EI&E), DASN I&F; Cariello, Lou V RDML OPNAV, N45; Davis, Ronald J CIV OPNAV N4, N4B; Kern, Erin M SES OPNAV, N46
Cc: Muilenburg, Bret J RADM NAVFAC HQ, 00; Douchand, Larry E SES NAVFAC HQ, EV; LaTorre, Jennifer SES NAVFAC HQ, 00; Duchnak, Laura S CIV NAVFAC HQ, BRAC PMO; Mitchell, Jayson D CAPT NAVFAC EXWC, 00; Korka, John RDML NAVFAC PAC N00/COMPACFLT N46; Banaji, Darius RDML NAVFAC LANT, N00/USFF, N01CE; Edelson, Mark K CAPT NAVFAC HQ, OPS; Curfman, Robert D SES NAVFAC HQ, PW; Edmonds, Antonio M CAPT CNIC, N4; Loeschke, Scott D I&L, GF
Subject: PFAS (incl PFOS & PFOA) LEARNING

Leaders: FYSA

We are all familiar with our efforts to test for PFOS & PFAS at our active and BRAC installations, to communicate results to the public, and mitigate with alternate drinking water. I spent last Friday at our Engineering & Expeditionary Warfare Center (EXWC) in Port Hueneme, CA. One the subject areas we discussed was their efforts to understand, treat, and minimize generation of PFOS and PFAS. EXWC's core competence is to take basic research from others and develop practical tactics, techniques, and procedures for employment at all Navy and Marine Corps installations. I thought you might also benefit from my learning and also from other Environmental Business Line team efforts underway.

Executive points include:
- These contaminants (PFCs) are found globally in the environment, resultant from many common uses. AFFF has a high concentration of these chemicals, thus it's receiving so much attention.
- Existing contaminant treatment techniques, like filtering with Granular Activated Carbon, have limited effectiveness. Several EXWC-led research efforts are underway in FY17 and proposed for FY18 to review and determine effective treatment solutions.
- We have a growing "storage" challenge. The field is accumulating contaminated solution, without clear direction about what to do with it. Our Environmental Business Line team has been working with OPNAV N45 and DASN (E) staffs to develop necessary disposal guidance.
- Commissioning of new AFFF firefighting systems and testing of existing systems has been a significant source of contaminant release. New techniques using surrogate "NoFoam" systems for commissioning and testing can drastically reduce non-emergency AFFF releases. The extent that our installations are using "NoFoam" systems is an unanswered question for me. It was suggested that in many AFFF applications, system operators are doing less routine equipment testing.

- We are also finalizing an inventory of unused AFFF supplies of the old 3M formulation that is very high in PFOS. Pending availability of funding, these legacy AFFF supplies will be disposed of later this year through the DLA disposal process.

The attached quad charts provide more detailed information.

Vr,
Bret

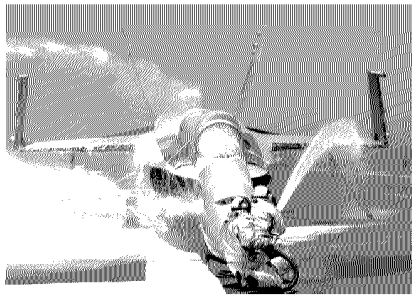
PFAS Challenges

PFASs (PFCs)

- PFASs (including PFOS & PFOA) are an extremely stable class of synthetic chemicals
- PFASs comprise thousands of compounds
- Carbon-fluorine bonds - the strongest bond in organic chemistry - imparts stability and unique properties
- Resistant to heat, chemical, and other degradation
- Persistent and bioaccumulative
- Repels both oil and water
- Most conventional treatments are ineffective - activated carbon effective for some PFASs

PFASs in EPA's Crosshairs

- Bioaccumulate in food chain and exhibit various toxicities
- Long half-lives in humans (5.4 years)
- Associated with some cancers, and immunological, endocrinological, and developmental problems
- Very mobile in-situ
- Water soluble
- Found globally



Common Uses, Widespread Occurrence

- Water and oil/stain resistance for textiles, paper (e.g. Scotchguard); non-stick coatings (e.g. Teflon)
- Component of aqueous film-forming foam (AFFF) used to fight fuel fires
- PFASs found in soil and water at Navy Installations where AFFF is used
- Some fire training areas contain over 1,000 ppb PFOS in groundwater
- Other PFASs (up to hundreds) also detected at AFFF sites
- Some AFFF formulations used by DoD have no (or trace) PFOS or PFOA, but have many other PFASs

Regulatory Framework

- PFASs are "emerging" contaminants
- No Safe Drinking Water Act (SDWA) standards or routine water quality testing requirements
- EPA Lifetime Health Advisory (LHA) level is 0.07 parts per billion (ppb) for PFOS and PFOA, individually or combined, for drinking water
- Toxicity of PFASs, other than PFOS and PFOA, still unknown; uncertainty in animal testing models leads to very low LHA
- Some States regulate other PFASs, have even lower action levels

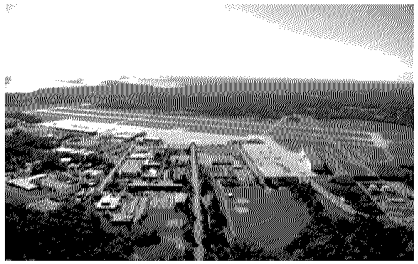
PFAS Solutions

Characterization of PFASs

- Understand the behavior of the various PFAS compounds in the environment in terms of sources, transport, and fate
- ESTCP, FY16 - Characterization of PFAS source areas and groundwater plumes at NAS Jacksonville, Travis AFB, JRB Willow Grove
  - Identify important site factors in fate and transport
  - Partnering with A&E and multiple universities
  - Final Report and Guidance for RPMs to be completed in FY19
- NESDI, FY16 - PFAS structural considerations on transport and exposure pathways
  - Final report and Decision Tool Q4 FY18
  - Updating workgroups as project progresses
- NESDI, FY17 – Effect of prior treatment for co-contaminants on PFASs
  - Prior treatment may have exacerbated PFASs
  - Final report and RPM Guidance Q2 FY19

Former NAS Brunswick

- EXWC provided input on groundwater extraction treatment system for removal of PFAS



Treatment of PFASs

- ESTCP, FY17 - Activated persulfate treatment of PFAS in soil and groundwater
  - In situ treatment of PFASs with pump and treat to eliminate source zones and accelerate site closure
  - Partnering with A&E and UC Berkeley
  - Final report FY 19
- NESDI, FY18 (full proposal submitted) - Evaluation of multiple treatments for removing PFAS from groundwater
- NESDI, FY18 (full proposal submitted) - Evaluation of treatment of PFAS in IDW and high concentration wastewater such as ship holding tanks

EXWC PFAS Laboratory

- Conduct testing of key plume migration parameters and PFAS treatment options
- Determine PFAS transport, leachability on in situ materials and soils from impacted sites

Technology Driven, Warfighter Focused

US00022414

NoFoam System

ARFF Vehicle & Hangar Systems

ARFF Vehicle discharge check using a NoFoam Trailer Sys.

Milestones/Accomplishments:

- Technology certified by the Environmental Security Technology Certification Program (ESTCP)
- Integrated at over 10% of DoD ARFF vehicle fleet.
  - Over 50 trailers units delivered
  - Over 225 ARFF vehicles being served
- Technology Licensed & commercially available
- Transitioned NoFoam technology to structural vehicles & Hangar fire suppression systems

Technology Description:

The NoFoam technology is designed to perform routine foam system checks of Aircraft Rescue Fire Fighting (ARFF) vehicles to ensure mission readiness w/o negatively impacting the environment.

Capabilities/Benefits Provided:

- Eliminates AFFF wastewater generation from foam system checks
- Improved ARFF vehicle mission readiness; promotes more frequent testing
- Reduces AFFF concentrate procurement
- Technology universal to DOD ARFF vehicles
- Diagnostic tool for vehicle foam proportioning sys.

NoFoam Hangar System

- Certified by the Environmental Security Technology Certification Program (ESTCP)
- Certifying System at Nationally Recognized Testing Lab (NRTL) – Required for Navy Firefighting community acceptance
  - Test Period: 3rd qtr. FY '17
  - NRTL certification and report: 4th qtr. FY '17
  - Test Analysis report: 4th qtr. FY '17

Diamond Materials for Solvated Electron Chemistry
Potential Payoff: Remediation of AFFF PFAS Contamination from Water
PI: Bradford Pate, code 6178

Poly- and per-fluoroalkyl substances (PFAS) are synthetic chemicals found in clothing, furniture, cookware, food packaging, cosmetics and aqueous film forming foam (AFFF or "firefighting foam"). In 1966 NRL patented the use of PFAS as a surfactant in AFFF.[1] PFAS are now known to be highly persistent, bioaccumulative, toxic, and have infiltrated numerous water sources in the United States. [2] Perfluorooctanoic acid (PFOA) and perfluorosulfonic acid (PFOS) are PFAS with an EPA health advisory level (HAL) of 70 parts per trillion in ground water (issued in June 2016). The 2016 health advisory reduced the advisory threshold for PFOS and PFOA contamination in municipal water supplies by an order of magnitude. NAVFAC has determined that the EPA HAL for PFASs have been exceeded at several Navy installations including NASJRB Willow Grove, NAS Warminster, NAS Brunswick, NAS Corpus Christi, and NAS Jacksonville. In August 2016, the U.S. Navy was sued for the first time over contamination exceeding the EPA advisory for PFOS and PFOA in ground water.[3] Today's focus on remediation are the so-called C8 class (eight carbon chain) of PFAS that specifically include PFOS and PFOA. However, a comprehensive remediation process that is effective not only for C8, but also shorter chain PFAS is called for.

Contrary to naturally occurring fluorinated compounds that typically contain a single fluorine atom, anthropogenic PFAS contain carbon backbones that are nearly saturated with fluorine. As a consequence these molecules are extremely recalcitrant, with no known biodegradation or abiotic degradation pathway, and persist on a decades time scale in the environment. [4] This coupled with aqueous solubility imparted by their functional head groups and weak sorption properties has resulted in far reaching, rapid contamination of water sources. [2] While the weak sorption properties of PFOA and PFOS to organics in the environment allow them to travel to remote regions of the Atlantic, Pacific and Arctic oceans, their interaction with proteins enable them to bioaccumulate resulting in high levels of PFAS being detected in animals and humans. PFAS exposure is a concern as these substances have been linked to cancer, obesity, high cholesterol, immune suppression and endocrine disruption. [5,6]

Standard wastewater treatment methods are not only ineffective for the removal of PFOS and PFOA, but also serve as a source, since labile precursors biodegrade into PFOS and PFOA. [7,8] Recent reports of fluorotelomer-based polymers (FTPs) have also implied these compounds may undermine efforts to reduce PFOAs for years to come by degradation into perfluorocarboxylic acids. [9] Although a number of treatment technologies have been demonstrated for PFOA and PFOS removal, such as reverse osmosis, nanofiltration, and activated carbon, the results are varied and include hazardous waste disposal of concentrated PFAS and/or economical constraints. [10] In this regard, concentrated PFAS disposal is not a trivial process and must include a sustainable approach that does not simply transfer PFAS waste from one hazardous form to another. Pyrolytic destruction though attractive and currently in practice, must address the release of fluorinated volatiles. Since the C-C bond is weaker than the C-F bond, the carbon chain is more susceptible to cleavage during incineration resulting in short chained fluorocarbons that may contribute to atmospheric contamination and potentially greater exposure to humans. Similarly advanced oxidation processes, which use chemicals, catalysts and light to oxidize chemicals with hydroxyl radicals, are prone to generating short chained PFAS intermediates that are more volatile along with deadly fluorine gas as a by product. [11]

Only strongly reductive processes have demonstrated the ability to separate fluorine atoms from the carbon chains of PFC, due to the extreme reduction potential (E) required to break the carbon-fluorine bond, $E < -2.7$ V vs. standard hydrogen electrode. And, in water, defluorination of PFAS is

recognized as being accessible only by aqueous electrons. [10] Our approach, direct injection of electrons into solution from negative electron affinity diamond, is a chemical free source of highly reductive aqueous electrons that would consequently provide a critical technology that is currently missing in the treatment and waste disposal of PFAS in water. An encounter of PFAS with aqueous electrons generates only fluoride ions and hydrocarbons (free hydrogen in solution replaces the fluorine), each of which can be removed by well-established wastewater treatment technologies. For fluoride removal from municipal water supplies, the EPA finds the most cost effective process often is the use of activated alumina for adsorption of fluoride via ligand exchange, with periodic regeneration of the activated alumina. [12] This is a well established technique that is widely used in the U.S. where the amount of naturally occurring fluoride in water exceed the recommended level of 700 ppb (factor of 10,000 above the health advisory limit for PFAS). The captured fluoride, is recovered periodically in a regenerative process that re-activates the alumina and converts the adsorbed fluorine ions to disposable metal salts (eg. CaF). There are numerous established adsorption or oxidation processes for removal of the remnant hydrocarbons from water.

1. R. L. Tuve and E. J. Jablonski, *Method of extinguishing liquid hydrocarbon fires*, USPTO, US3258423, 28-Jun-1966.
2. Hu, X.C., et al., *Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants.* Environmental Science & Technology Letters, 2016.
3. M. Fair, *US Navy Hit With First Suit Over Pa. Base Contamination,* Law360, website: http://www.law360.com/articles/832099/us-navy-hit-with-first-suit-over-pa-base-contamination, 24-Aug-2016 (retrieved 28-Sep-2016).
4. *Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)*, E.P. Agency, Editor. 2016. p. 103.
5. Barry, V., A. Winquist, and K. Steenland, *Perfluorooctanoic Acid (PFOA) Exposures and Incident Cancers among Adults Living Near a Chemical Plant.* Environmental Health Perspectives, 2013. **121**(11-12): p. 1313-1318.
6. Grandjean, P., et al., *SErum vaccine antibody concentrations in children exposed to perfluorinated compounds.* JAMA, 2012. **307**(4): p. 391-397.
7. Loganathan, B.G., et al., *Perfluoroalkyl sulfonates and perfluorocarboxylates in two wastewater treatment facilities in Kentucky and Georgia.* Water Research, 2007. **41**(20): p. 4611-4620.
8. Schultz, M.M., et al., *Fluorochemical Mass Flows in a Municipal Wastewater Treatment Facility.* Environmental Science & Technology, 2006. **40**(23): p. 7350-7357.
9. Washington, J.W., et al., *Decades-Scale Degradation of Commercial, Side-Chain, Fluorotelomer-Based Polymers in Soils and Water.* Environmental Science & Technology, 2015. **49**(2): p. 915-923.
10. Vecitis, C.D., et al., *Treatment technologies for aqueous perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA).* Frontiers of Environmental Science & Engineering in China, 2009. **3**(2): p. 129-151.
11. Arias Espana, V.A., M. Mallavarapu, and R. Naidu, *Treatment technologies for aqueous perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA): A critical review with an emphasis on field testing.* Environmental Technology & Innovation, 2015. **4**: p. 168-181.
12. F. Rubel, *Removal of Fluoride from Drinking Water Supplies by Activated Alumina*, 2nd ed. US EPA, EPA/600/R-14/236, Sep. 2014.

From: Ahmed, Farhad
Sent: 3 Oct 2016 19:38:39 +0000
To: Werner, Lora;Watkins, Sharon;Sivarajah, Kandiah
Subject: RE: Question re PFAS in fish near Willow Grove/Warminster area; current DRAFT version of ATSDR's Horsham Q&A for your eyes only
Attachments: CLEAN CDC Horsham PFC Health Questions Draft- post Lynn.docx

Hi Lora,

We have looked at the responses and they seem to be ok. There is just one typo- line 4 should read Willow Grove (not Willow Grover). Otherwise looks fine. Thank you for sharing with us.

Farhad Ahmed, MBBS, MPH| PI & Health Assessment Section Chief
Pennsylvania Department of Health
Bureau of Epidemiology
[redacted]
www.health.state.pa.us

From: Werner, Lora [mailto[redacted]
Sent: Friday, September 30, 2016 4:02 PM
To: Watkins, Sharon <[redacted]>; Ahmed, Farhad <[redacted]>; Sivarajah, Kandiah <[redacted]>
Subject: RE: Question re PFAS in fish near Willow Grove/Warminster area; current DRAFT version of ATSDR's Horsham Q&A for your eyes only

Thanks Sharon and Farhad. Raising this public health data gap to our partners is exactly what I was trying to do today with my email, I really appreciate PADOH's help. I have been bringing this up to EPA and DOD for a while now, and there has been low interest so far, but I plan to keep raising the issue on the federal side. I have not talked about it with PADEP at all before today, when I brought it up to Ragesh.

FYI, this is the current version of our draft Q&A for Horsham Township's website (please do not circulate outside yourselves). It is at the last round of technical review. If PADOH has any concerns about these responses, please let me know by early next week. Are you guys also working on responses?
Lora

Lora Siegmann Werner, MPH
Regional Director, Region 3
Division of Community Health Investigations
Agency for Toxic Substances & Disease Registry (ATSDR)/Centers for Disease Control & Prevention
[redacted]

Philadelphia, PA 19103

[redacted]

From: Watkins, Sharon [redacted]
Sent: Friday, September 30, 2016 2:54 PM
To: Ahmed, Farhad <[redacted]; Werner, Lora <[redacted]>; Sivarajah, Kandiah [redacted]
Subject: RE: Question re PFAS in fish near Willow Grove/Warminster area

Have we had discussions with DEP that fish sampling for this site may be necessary from a public health point of view? Farhad, could that be something we try to engage our partners in, not sure if that is DEP or Fish and Boat or? Sharon

---

From: Ahmed, Farhad
Sent: Friday, September 30, 2016 12:09 PM
To: Werner, Lora <[redacted]; Sivarajah, Kandiah <[redacted]>; Patel, Ragesh <[redacted]>; Lin, Willie CIV NAVFAC HQ, BRAC PMO <[redacted]>; Johnson, KarenD <[redacted]>
Cc: Watkins, Sharon <[redacted]>; Markiewicz, Karl <[redacted]>; Lloyd, Christine <[redacted]>; Helverson, Robert <[redacted]>; Leonard, Paul <[redacted]>; Kloss, Sarah <[redacted]>; Cunningham, Lisa Bradford <[redacted]>
Subject: RE: Question re PFAS in fish near Willow Grove/Warminster area

Hi Lora,

I have discussed with Dr. Siva your draft response below which looks ok. Just a couple of comments:

Pennsylvania (PADEP and Fish & Boat Commission) currently does not sample PFOS, PFOA in fish.
PA has a blanket statement of one-meal-per-week fish consumption advisory that applies to both recreationally caught fish as well as to trout stocked in PA waters.

Thank you.
Farhad

Farhad Ahmed, MBBS, MPH| PI & Health Assessment Section Chief
Pennsylvania Department of Health
Bureau of Epidemiology
[redacted]
www.health.state.pa.us

From: Werner, Lora [r[redacted]
Sent: Friday, September 30, 2016 10:55 AM
To: Sivarajah, Kandiah <[redacted]>; Ahmed, Farhad <[redacted]>; Patel, Ragesh <[redacted]>; Lin, Willie CIV NAVFAC HQ, BRAC PMO <[redacted]>; Johnson, KarenD <[redacted]>
Cc: Watkins, Sharon <[redacted]>; Markiewicz, Karl <[redacted]>; Lloyd, Christine <[redacted]>; Helverson, Robert <[redacted]>; Leonard, Paul <[redacted]>; Kloss, Sarah <[redacted]>; Cunningham, Lisa Bradford <[redacted]>
Subject: Question re PFAS in fish near Willow Grove/Warminster area

Hi there colleagues

ATSDR is working on follow up questions from the 8/29 Horsham PFAS health panel meeting to be posted on Horsham Township's website. There is a question about consuming fish from local creeks in the Warminster/Willow Grove area. This is a question that is not going away, and ATSDR sees this as a current public health data gap that needs to be addressed. We stated this in our 1/16 Warminster Letter Health Consultation document, and I expect we will do so more strongly in our forthcoming Willow Grove Letter Health Consultation. Until we have actual fish sampling data from the site area, we can't really answer this question, but I tried to put together a response on what we can say now. Please see below for this draft response – do any of you have any comments on this?

I heard at one point that maybe there had been some limited discussions at the state (PADEP? Fish & Boat? PADOH?) on this topic already? Ragesh, thanks for speaking with me about this issue this morning, I appreciate any follow up can track down on this issue on the PADEP side. I called the general number for PA Fish and Boat this morning and the clerk there did not have any information on this topic, and had me leave a message for Rick Levitz (sp?), their public relations contact. Siva, Farhad – not sure if you have heard anything on the PADOH side. Any feedback any of you can share would be very much appreciated.

Lora

---

6. Can we eat fish that we catch in local creeks?

(b)(5)

(b)(5)

Lora Siegmann Werner, MPH
Regional Director, Region 3
Division of Community Health Investigations
Agency for Toxic Substances & Disease Registry (ATSDR)/Centers for Disease Control & Prevention

[redacted]

From: Morefield, Deborah A CIV OSD OUSD ATL (US)
To: Mach, Richard CIV OASN (EI&E), ODASN (Environment); Tesner, John E CIV USARMY HQDA ASA IEE (US); Fairlie, Catherine A CIV USAF SAF-IE (US); [redacted]; Miller, Edmund D CIV OSD OUSD ATL (US)
CC: Morefield, Deborah A CIV OSD OUSD ATL (US); Long, Alexandria D CIV OSD OUSD ATL (US); Parker, Amy [USA]; Routt, Christine [USA]
Sent: 5/13/2015 12:51:45 PM
Subject: DoD PFC talking points for mtg w/EPA
Attachments: Emerging Contaminants Visuals 05122015.pptx; PFOA timeline_may2015.docx; Talking Points for PFC meeting with EPA_May2015.docx

Good morning,

Attached are the proposed talking points for the meeting with EPA regarding PFCs. Please look closely at item #2 on the DERP procedures. Also, item #4 we tried to capture a universe of sites - I was hoping these numbers would show we do not have a big issue however with the large number for the AF it may not be wise to go this path.

Also, the attached power point to show what occurs if an EC is discovered at some point during cleanup process and how DoD incorporates into cleanup and the 2nd slide illustrates how discovery of an EC release to the environmental fits in the CERCLA. The 3dr slide just reinforces DoD policy and procedures are based on the ECOS trigger paper. Thoughts on using the slides to support the DoD discussion?

For backup, I also included a timeline of events related to PFOS/PFOA - I know the format needs work but just wanted to capture a general timeline of events.

Look forward to your thoughts/edits. Appreciate the discussion and quick turnaround.

VR,
Deb

deborah morefield, CHMM
OASD (EI&E)/ESOH
[redacted]

Talking Points for DoD – EPA Discussion on Emergent Contaminants: PFOS/PFOA

1. Drinking water – Sampling based on the Safe Drinking Water Act (SDWA) Unregulated Contaminant Monitoring Rule 3 (UCMR3) and if there is a risk takes appropriate action.
2. Defense Environmental Restoration Program (DERP) procedures
    - Review current inventory of potential sources and review records for other potential sources
    - Prioritize sites where there has been a release or suspected release based on risk
    - Perform site investigations, characterize sites, and implement containment measures, where necessary
    - Concern there is no in situ technology to address so contain contamination

[redacted]

4. Number of sites/potential sites:
    - Navy - approximately 350 sites; about half are existing sites.
    - AF - about 1,000 sites; about 1/3 are existing sites. It's unclear whether this include BRAC or not; AF BRAC has already added 50 new sites that are really duplicate fire training area sites.
    - Army – [Need Army to provide # of sites] sites.
    - FUDS - PFCs weren't used much at FUDS properties because they were introduced in the 1970s and FUDS properties were transferred from DoD control prior to October 17, 1986.